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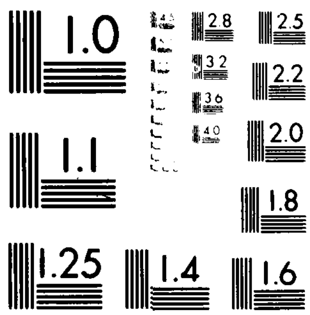


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# SYSTEM ENGINEERING ANALYSIS OF LIQUID CARGO HANDLING SYSTEM INSTALLED ON AO-177, AOE-1, AND AOR-1 CLASS SHIPS

February 1982

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
COMBAT SUPPORT SHIPS
HUNTERS POINT NAVAL SHIPYARD
SAN FRANCISCO, CALIFORNIA
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The analysis documented herein is specifically applicable t to the Liquid Cargo Handling System (LCHS), ship's work authorization boundaries (SWAB) groups 544-1 and 544-2 installed on AO-177, AOE-1, and AOR-1 Class ships. It considers only the systems and equipments installed and documentation effective as of 30 Sept. 1981. This system was selected for analysis by PERA (CSS) on the basis of its mission criticality and historical maintenance burden.

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by

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## SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the material condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the Liquid Cargo Handling System (LCHS) installed on AO-177, AOE-1, and AOR-1 Class ships.

This report was developed for PERA (CSS) under Delivery Order FJ06 of Navy Contract N00189-81-D-0126.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance strategy and specific maintenance actions best suited to meeting EOC goals.

The major findings and conclusions of the SEA for the AO-177, AOE-1, and AOR-1 Class Liquid Cargo Handling System are summarized as follows:

- Generally, similar equipment types exhibited the same maintenance problems.
- The LCHS pump performance will slowly degrade because of the normal wearing of internal parts. Significant reductions in performance or pump failures can be expected to occur to a majority of the pumps installed by or during the fifth operational year. Pump overhauls every four years should be sufficient to maintain adequate LCHS subsystem performance.
- Configuration differences will affect the maintenance strategies of AOE-3 and AOE-4. These two ships have a much greater fuel oil pumping capacity than the other combat support ships and therefore could be allowed to operate longer between overhauls without significantly affecting the ships' logistics mission capabilities as defined in this report.

* Ship's force personnel cannot accomplish major repairs, in a timely fashion, to the following LCHS equipments:
    * Liquid cargo pumps
    * Valves located in or on fuel oil tanks
    * Valves that have one side open to the sea
    * Valves 18 IPS or larger
    * Hydraulic actuators located in or on fuel oil tanks
* The following LCHS components should receive class B overhauls at the depot level:
    * Cargo pumps
    * Stripping pumps
    * Motors
    * Certain valves
    * Certain hydraulic actuators
    * Turbine governors
* No individual valve or indicator exhibited a notable maintenance burden. However, the aggregate of each component group presented a significant maintenance burden for ship's force and IMAs.
* Lube oil cleanliness is the most significant factor affecting turbine and turbine governor availability.
* General LCHS maintenance accounted for an average of 115 maintenance man-hours per ship operating year. No individual repair in the category occurred frequently enough or on a regular enough basis to warrant planned intracycle maintenance. However, it is anticipated that these maintenance actions will continue to occur randomly during future operating cycles.

CONTENTS

CONTENTS (continued)

*CHAPTER ONE*

# INTRODUCTION

## 1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Mobile Logistic Support Force (MLSF) in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of a SEA is to define and document a maintenance program that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

## 1.2 SCOPE

The analysis documented herein is specifically applicable to the Liquid Cargo Handling System (LCHS), ship's work authorization boundaries (SWAB) groups 544-1 and 544-2 installed on AO-177, AOE-1, and AOR-1 Class ships. It considers only the systems and equipments installed and documentation effective as of 30 September 1981. This system was selected for analysis by PERA (CSS) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, ship alteration and repair packages (SARPs), system alteration information, system technical manuals, and Destroyer Engineered Operating Cycle (DDEOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on DDEOC Program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

## 1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the Liquid Cargo Handling Systems as installed on individual ships of the ship classes under study. Appendix C presents a summary of the LCHS cargo pump differences and describes the subsystem effects of pump losses. Appendix D presents a summary of the LCHS CASREPs by LCHS design and CASREP cause. The status of LCHS shipalts is summarized in Appendix E.

*CHAPTER TWO*

# APPROACH

## 2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the Liquid Cargo Handling System installed on AO-177, AOE-1, and AOR-1 Class ships. The system was selected for analysis by PERA (CSS) on the basis of its mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the system's operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major tasks of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe these major tasks.

## 2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

In Task 1, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared to describe the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks.

### 2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled from appropriate technical manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on DDEOC Program ships.

The MDS data bank was compiled by examining all MDS data reported for hulls AO-177, AOE-1 through -4, and AOR-1 through -7 (a total of 12 ships) from 1 January 1975 through 30 July 1981.

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period 1 January 1978 through 31 July 1981. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

### 2.2.2 Define System Configuration

Configuration information was obtained by reviewing available common configuration class lists (CCCLs), the type commander's coordinated shipboard allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, confirmed system configuration.

### 2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analysis of MDS and CASREP data and review of applicable PMS documentation and SARPs. The maintenance history profile is a working technical package describing the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

## 2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In Task 2 the data summarized on the maintenance history profile form were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were identified through discussion with ships' forces and Navy technical personnel when possible.

### 2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and material condition of the equipments constituting the system were identified by screening the maintenance history profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems that require IMA, depot, or other off-ship assistance for correction and are common to all engineering designs of the functionally similar equipments installed on the ship classes examined
- Identification of recurring failure modes or problems that are either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls

Once the problems were identified, the previously completed DDEOC Program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

### 2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process, concurrent with definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of identical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories: maintenance strategy, design, and support.

### 2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in progress, applicable alterations, or the effects of availabilities

## 2.4 TASK 3: DEVELOP SOLUTIONS FOR PROBLEMS

In Task 3 the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, design changes for the associated equipments, or equipment that should be replaced.

### 2.4.1 Analyze Existing Solutions

The analysis of existing design solutions that may be applicable to the three ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To do

so, currently authorized shipalts affecting the system or equipment under study were reviewed and, if necessary, interviews were conducted with Navy technical personnel.

The second objective was to determine if the specific problem existed in other ship classes and, if it did, whether a solution had been defined and whether that solution was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated for similarity. If the problems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on the ship classes under study. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

### 2.4.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on the ship classes under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ships.

Where previously identified maintenance strategies did not apply to the ship classes under study, maintenance strategies that could possibly apply were analyzed by using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. Three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating level is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

### 2.4.3 Analyze Potential Solutions to Integrated Logistics Support (ILS) Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of ILS problems. Such problems are typically identified during review of MDS or

CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. Where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. Otherwise, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

### 2.4.4 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses or functionally similar equipments, that were judged to improve personnel safety or primary mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible or their value in terms of reduced maintenance burden or improved equipment reliability was not significant, they were not recommended for implementation.

## 2.5 TASK 4: DOCUMENT SEA RESULTS

The Task 4 approach was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the equipment configurations by allowance parts list (APL) number for each hull included in the analysis.

*CHAPTER THREE*

# RESULTS

## 3.1 SYSTEM BOUNDARIES AND DESCRIPTION

The liquid cargo handling systems (LCHS) discussed in this report are composed of those equipments included within SWAB groups 544-1 and 544-2. All the major equipments, listed in Appendix A by SWAB group, were examined to identify maintenance requirements. The major components examined and discussed in this report are listed by APL number in Appendix B. Minor components such as light indicators, filters, and small valves were not examined in detail, because past experience has shown that these components are not maintenance- or mission-critical and are usually repaired or replaced as necessary by ship's force and thus require no periodic repairs.

Each LCHS installed on the AO-177, AOE-1, and AOR-1 Class ships, hereafter referred to as the combat support ships, is composed of several subsystems, each designed to receive, stow, strip, and transfer a specific type of liquid cargo. Each subsystem is composed of cargo pumps and associated drivers; stripping pumps and associated drivers; and the piping, valves, controls, and indicators necessary to control and monitor the flow of liquids between the replenishment stations and the stowage tanks. AOE-1 and AOR-1 Class ships are equipped with aviation gas (AVGAS), distillate fuel marine (DFM), and JP-5 liquid handling subsystems. AO-177 Class ships are equipped with JP-5 and DFM liquid handling subsystems.

The AVGAS subsystems are being removed from the AOE-1 and AOR-1 Class ships. Discussions with ship's force personnel indicate that the AVGAS subsystems still installed on the combat support ships are not used. Therefore, discussions will be limited to the JP-5 and DFM subsystems installed on the combat support ships.

The loss or degradation of the LCHS affects each ship's ability to supply fuel to combatant ships. Logistics -- the resupply of combat consumables to combatant forces in the theater of operations by logistics support forces -- is a primary mission area for the combat support ships.

The extent of LCHS degradation can be determined from the number of inoperative cargo pumps per subsystem. Table C-1 of Appendix C lists the cargo pump differences by LCHS design. Ships that have identical LCHSs have been grouped together. Different ships have different numbers of

cargo pumps within given LCHS subsystems, and not all cargo pumps have the same pumping capacities. Therefore, the loss of an individual cargo pump does not always affect all the combat support ships to the same extent. Table C-2 of Appendix C shows how the loss of different cargo pumps affects the total capacities of the LCHS subsystems.

The loss of one DFM or JP-5 cargo pump does not critically affect either subsystem; fuel oil could still be delivered to two combatants simultaneously. In most cases, the loss of two DFM cargo pumps would reduce the total DFM pumping capacity by approximately one-third. AOE-1 and -2 and all the AOR-1 Class ships could still deliver DFM at a rate of 3,000 gpm to each of four stations with two cargo pumps inoperable. This is the maximum rate at which most cruisers or destroyers are designed to receive DFM. Practical experience indicates that these ships will ordinarily receive DFM at lower rates per station. In the worst case, if AOE-3 or -4 or AO-177 Class ships lost two DFM cargo pumps, they could still deliver 2,500 gpm of DFM to each of four stations. Therefore, all the combat support ships could sustain the loss of two DFM cargo pumps and still be able to deliver sufficient quantities of DFM to the average cruiser or destroyer (four stations simultaneously). The loss of three DFM cargo pumps would preclude efficient four-station operation for the AO-177 Class ships; might preclude efficient four-station operation for the AOE-3 and -4, depending on which size pumps are lost; and would not significantly affect replenishment-at-sea operations for AOE-1 and -2 and the AOR-1 Class ships. The loss of four DFM cargo pumps precludes the simultaneous replenishment of two combatants (two stations each) for all combat support ships.

JP-5 is used primarily for diesel machinery and various types of aircraft. The average destroyer or cruiser has little need for large quantities of JP-5. Therefore, aircraft carriers have been used as a base in determining the minimum JP-5 pumping capacity needed for the combat support ships.

It is assumed that aircraft carriers can receive 3,000 gallons of JP-5 per minute per station at two stations simultaneously. It is very unlikely that two aircraft carriers would refuel simultaneously; therefore, the ability to pump 6,000 gallons of JP-5 per minute is considered 100 percent capable.

All combat support ships would still be 100 percent capable with the loss of one JP-5 pump. The loss of two pumps would cause AOE-1 and -2 and all AOR-1 and AO-177 Class ships to be only 50 percent JP-5 capable. AOE-3 and -4 would still be 100 percent JP-5 capable in this instance. The loss of three pumps would eliminate all JP-5 capability for all combat support ships except AOE-3 and -4, which would then be 50 to 100 percent JP-5 capable, depending on which pumps were lost. The loss of four JP-5 pumps would reduce the AOE-3 and -4 JP-5 capability to zero.

LCHS design differences on combat support ships other than those already mentioned are not discussed in this report unless they are responsible for a significant difference in the maintenance histories of the various LCHS installations. For the purposes of this report, "significantly

different" is defined as a maintenance parameter difference of more than 100 percent. One hundred percent was selected because past experience has shown that the maintenance reporting practices among ships may differ a great deal, even though the actual maintenance experiences are similar. It is anticipated that a factor of 100 percent should compensate for most of these reporting inconsistencies.

## 3.2 MAINTENANCE REQUIREMENT IDENTIFICATION

AO-177 reported a total of eight records for the liquid cargo handling system during the MDS data period -- an insufficient quantity of data for the development of meaningful results. It is recommended that the general maintenance strategies developed in this report for AOE-1 and AOR-1 Class ships be adopted for the AO-177 Class LCHS until sufficient maintenance data are available to determine an appropriate maintenance strategy for the AO-177 Class LCHS.

The maintenance data were initially screened to identify those generic component groups which contributed to the reported LCHS maintenance burden, and the relative extent of each contribution. Maintenance burden summaries of the component groups identified are presented in Table 3-1. The burdens shown represent the combined maintenance burdens of all the LCHS components listed in Appendix B. The individual component burdens are grouped into seven general categories as described in the following paragraphs.

The maintenance burden data presented in Table 3-1 under the pump component group includes all data reported in the MDS for all AOE-1 and AOR-1 Class AVGAS, NSFO, and DFM pumps, and their associated couplings.

*Table 3-1.* SUMMARY OF MDS DATA FOR LCHS

| Component Group | Applicable Ships | Man-Hours | | | Total Man-Hours per Ship Operating Year |
|---|---|---|---|---|---|
| | | Ship's Force | IMA | Total | |
| **Turbines** | **AOE-1 through -4** | **4,508** | **716** | **5,224** | **246.9** |
| **Valves** | **All AOEs and AORs** | **5,589** | **1,728** | **7,317** | **127.4** |
| **Pumps** | **All AOEs and AORs** | **3,555** | **1,060** | **4,615** | **80.3** |
| **Controls and Indicators** | **All AOEs and AORs** | **2,000** | **900** | **2,900** | **50.5** |
| **Actuators** | **All AOEs and AORs** | **939** | **48** | **987** | **17.2** |
| **Motors** | **All AOEs and AORs** | **217** | **127** | **344** | **5.9** |
| **Other System-Related Maintenance** | **All AOEs and AORs** | **1,577** | **5,017** | **6,594** | **114.8** |
| **Total** | | 18,385 | 9,596 | 27,981 | **487.0** |

The turbine component group includes the MDS data reported for all AOE-1 Class cargo pump turbines. This group also includes all maintenance data reported for turbine governors, lube oil subsystems, steam admission and relief valves, and reduction gears.

The control/indicator component group includes all MDS data reported against the AOE-1 and AOR-1 Class LCHS meters, gages, tank level indicators, tachometers, and control consoles and panels.

The valve component group includes all maintenance reported for AOE-1 and AOR-1 Class valves larger than three-inch pipe size (IPS). This group also includes all LCHS relief valves not included in previous component groups.

Actuators are all LCHS valve drivers. All LCHS robot arms and hydraulic actuating equipment are included in this component group.

The motor component group includes all AOE-1 and AOR-1 Class LCHS motors used to drive various cargo pumps, all starter motors, and related motor controllers.

System-related maintenance includes all other LCHS maintenance not included in the component groups described above. Maintenance actions such as cargo tank cleaning and repairs, cargo piping repairs, flange shield repairs, and manufacturing of new flash screens are included in this category.

The available MDS and CASREP data for each of the component groups listed in Table 3-1 were examined to identify the possible existence of significant maintenance-related problems unique to a particular engineering design, as discussed in Section 2.3. Generally, it was found that similar types of equipments were experiencing the same maintenance problems. The LCHS components have therefore been grouped into seven general component groups and are discussed as part of these component groups for ease of presentation. Exceptions are specifically addressed.

The following subsections present the significant failure modes identified for each LCHS component group, and the associated corrective maintenance and maintenance recommendations. A failure is defined as any malfunction or condition that, if left uncorrected, will immediately or eventually degrade the LCHS availability and reduce mission capabilities. Routine repair items -- those equipment malfunctions or conditions which are usually easily corrected by ship's force personnel -- are presented without detailed discussions. The subsections are as follows: Turbines, 3.2.1; Valves, 3.2.2; Pumps, 3.2.3; Controls and Indicators, 3.2.4; Actuators, 3.2.5; Motors, 3.2.6; Other System-Related Maintenance, 3.2.7.

The LCHS maintenance strategies are discussed in Section 3.3. All recommendations are summarized by type and component in Chapter Four.

Appendix D presents a summary of the LCHS CASREPs by LCHS design and CASREP cause. A summary and status of LCHS shipalts is presented in Appendix E.

### 3.2.1 Turbines

#### 3.2.1.1 Discussion

Approximately 19 percent of the LCHS maintenance burden reported in the MDS by the AOE-1 and AOR-1 Class ships was reported against the AOE-1 Class turbines (see Table 3-1). (All AOR-1 Class ships have motor-driven LCHS pumps.) Table 3-2 shows the reported maintenance burden for the LCHS turbine components by turbine design. This table also shows the average maintenance man-hours per subsystem or component operating year. The information presented in this table indicates that the AOE-1 Class ships have reported more maintenance against the control elements than any other general category of components. Relatively little maintenance has been reported against the other individual component groups or subsystems.

The following subsections address the significant repetitive failure modes and maintenance actions identified during the examination of the LCHS turbine maintenance data.

##### Significant Maintenance Actions

Table 3-3 summarizes the significant maintenance actions reported against the AOE-1 Class LCHS turbines. It shows the number of equipment maintenance actions reported for each failure mode or problem. (An equipment maintenance action is defined as a corrective action performed on an equipment in direct response to the occurrence of a particular significant failure mode.) Table 3-3 also shows the maintenance man-hours reported for each failure mode. (The table includes incomplete maintenance actions.)

For the turbines, there were few significant repetitive failure modes warranting periodic outside assistance, indicating that ship's force personnel can adequately maintain the LCHS turbines.

Four repetitive failure modes or problems were reported for the LCHS turbine governors. In most cases, ship's force personnel were able to correct the problems with little or no outside assistance. The turbine governors were not the subject of CASREPs during the CASREP data period (see Table D-1 of Appendix D). However, when governor adjustment or resetting was required, outside assistance was usually requested. AOE-3 and -4 reported significantly more of this type of action than the first two ships of the class. Further examination showed that AOE-3 had reported all 27 of the equipment maintenance actions during 1976 and 1977. The problem was not reported again by AOE-3 during the MDS data period. Ship's force interviews revealed that a few technicians had attended a governor maintenance school and that governor adjustments were now accomplished with a minimum of effort. Therefore, governor adjustments are not expected to require significant expenditure of ship's force man-hours or IMA man-hours in the future and scheduled IMA assistance is not necessary.

Table 3-2. LCHS MAN-HOUR SUMMARY: TURBINES

| Subsystem or Component | Subsystem or Component Maintenance Man-Hours | | | | | | | | Average Maintenance Man-Hours per Subsystem or Component Operating Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AOE-1 | | AOE-2 | | AOE-3 and -4 | | All Hulls | | AOE-1 | | AOE-2 | | AOE-3 and -4 | | All Hulls | |
| | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA |
| 1. Control Elements | | | | | | | | | | | | | | | | |
| a. Governor | 232 | 4 | 138 | 0 | 2,546 | 352 | 2,916 | 356 | 47.2 | 0.8 | 24.5 | 0.0 | 240.4 | 33.2 | 137.9 | 16.8 |
| b. Steam admission valve | 250 | 0 | 80 | 0 | 20 | 0 | 350 | 0 | 50.8 | 0.0 | 14.2 | 0.0 | 1.9 | 0.0 | 16.5 | 0.0 |
| c. Throttle valve | 10 | 0 | 0 | 0 | 4 | 0 | 14 | 0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.7 | 0.0 |
| d. Other | 0 | 0 | 0 | 0 | 25 | 0 | 25 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 0.0 | 1.2 | 0.0 |
| Subtotal | 492 | 4 | 218 | 0 | 2,595 | 352 | 3,305 | 356 | 100.0 | 0.8 | 38.6 | 0.0 | 245.0 | 33.2 | 156.3 | 16.8 |
| 2. Turbine Internals | | | | | | | | | | | | | | | | |
| a. Bearings | 172 | 0 | 0 | 0 | 243 | 140 | 415 | 140 | 34.9 | 0.0 | 0.0 | 0.0 | 22.9 | 13.2 | 19.6 | 6.6 |
| b. Carbon rings | 110 | 0 | 0 | 0 | 0 | 0 | 110 | 0 | 22.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.2 | 0.0 |
| c. Other | 18 | 0 | 14 | 45 | 121 | 0 | 153 | 45 | 3.6 | 0.0 | 2.5 | 7.9 | 11.4 | 0.0 | 7.2 | 2.1 |
| Subtotal | 300 | 0 | 14 | 45 | 364 | 140 | 678 | 185 | 60.9 | 0.0 | 2.5 | 7.9 | 34.4 | 13.2 | 32.1 | 8.7 |
| 3. Lube Oil Subsystem | | | | | | | | | | | | | | | | |
| a. Cooler | 140 | 58 | 40 | 52 | 0 | 0 | 180 | 110 | 28.4 | 11.8 | 7.1 | 9.2 | 0.0 | 0.0 | 8.5 | 5.2 |
| b. Sump | 20 | 0 | 0 | 0 | 10 | 0 | 30 | 0 | 4.1 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 1.4 | 0.0 |
| c. L.O. pump | 0 | 0 | 0 | 0 | 60 | 0 | 60 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 | 0.0 | 2.8 | 0.0 |
| Subtotal | 160 | 58 | 40 | 52 | 70 | 0 | 270 | 110 | 32.5 | 11.8 | 7.1 | 9.2 | 6.6 | 0.0 | 12.8 | 5.2 |
| 4. Reduction Gear | 0 | 0 | 0 | 0 | 73 | 0 | 73 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.9 | 0.0 | 3.4 | 0.0 |
| 5. Lagging | 20 | 0 | 0 | 0 | 89 | 32 | 109 | 32 | 4.1 | 0.0 | 0.0 | 0.0 | 8.4 | 3.0 | 5.2 | 1.5 |
| 6. Other or Unknown | 71 | 0 | 2 | 0 | 0 | 33 | 73 | 33 | 14.4 | 0.0 | 0.4 | 0.0 | 0.0 | 3.1 | 3.4 | 1.6 |
| Total | 1,043 | 62 | 274 | 97 | 3,191 | 557 | 4,508 | 716 | 211.9 | 12.6 | 48.6 | 17.2 | 301.3 | 52.6 | 213.1 | 33.8 |

| Table 3-3. SIGNIFICANT FAILURE MODES: TURBINES | | | | | | |
|---|---|---|---|---|---|---|
| Failure Modes | AOE-1 and -2 | | | AOE-3 and -4 | | |
| | Equipment Maintenance Actions | Ship's Force Man-Hours | IMA Man-Hours | Equipment Maintenance Actions | Ship's Force Man-Hours | IMA Man-Hours |
| 1. Governors | | | | | | |
| a. Governor valves leak, stuck | 5 | 122 | 0 | 20 | 717 | 0 |
| b. Operation unstable | 7 | 7 | 4 | 0 | 0 | 0 |
| c. Out of adjustment | 2 | 41 | | 27 | 980 | 348 |
| d. Air control regulator erratic | 0 | 0 | 0 | 10 | 351 | 0 |
| e. Overhaul needed | 2 | 122 | 0 | 4 | 91 | 0 |
| 2. Lube Oil Subsystem | | | | | | |
| a. Coolers clogged, dirty | 6 | 140 | 58 | 0 | 0 | 0 |
| b. Lube oil sump dirty | 1 | 10 | 0 | 0 | 0 | 0 |

AOE-1 and -2 will periodically require IMA assistance to acid-clean the lube oil coolers (see Table 3-3). AOE-1 reported this maintenance action on six occasions in 4.9 years. The average completed maintenance action required approximately 20 IMA man-hours. These maintenance actions were reported in groups of three approximately every 2.5 years. Since this maintenance action is expected to reoccur, it is recommended that 60 IMA man-hours be reserved every 2.5 years to flush, chemically clean, and repair three lube oil coolers for the AOE-1 and -2. The lube oil coolers installed on AOE-3 and -4 can be adequately cleaned by ship's force personnel.

PMS Review

Review of the applicable technical manuals, discussions with ship's force and technical personnel, and past experience with other turbine-driven equipments all indicate that the single factor which assures maximum turbine and governor operational life is the cleanliness of the lube oil. This factor is particularly applicable to Woodward governors (installed on AOE-3 and -4 LCHS turbines).

PMS maintenance index pages E-36/8-AO, E-36/7-90, and E-36/11-40 require sampling the turbine lube oil before each operation and when the turbine has been idle for seven days, and cleaning the lube oil sump and renewing the lube oil every quarter. Two of the MIPs also require cleaning the lube oil sump and renewing the oil on the basis of results of visual lube oil inspection. It is recommended that task Q-3 of MIP E-36/8-AO (AOE-1) be changed to Q-3R and that a note be added to accomplish this task quarterly and when directed as a result of lube oil inspection (R-1), to ensure a long operational life and for maintenance consistency.

Two MIPs also require daily inspection of the lube oil during turbine operation. To assure maintenance consistency and to promote the maximum operational life of the turbine, it is recommended that the note of task R-1W of MIP E-36/11-AO (AOE-3, -4) include "daily when operating."

AOE-3 and -4 turbine governors have their own lube oil systems, separate from that of the turbine. MIP E-36/11-AO lists an 18M-3R requirement to renew the governor lube oil, but there is no requirement to check the governor lube oil during the 18 months. PMS task R-1W (sample and inspect the lube oil) does not include the governor lube oil. The AOE-1 and -2 governor lube oil is renewed at least once each quarter, as required by PMS. Review of Tables 3-2 and 3-3 indicates that AOE-1 and -2 have reported significantly fewer governor-related corrective maintenance actions and man-hours than AOE-3 and -4. Analyses performed on other turbine-driven equipments have also found that the Woodward governors (installed on the AOE-3 and -4 LCHS turbines) are particularly vulnerable to dirty lube oil. Prior analyses have also found that when the Woodward governor lube oil is not sufficiently clean the governors become sluggish and erratic before failure. These are the same symptoms often reported by AOE-3 and -4. Therefore, to reduce the frequency of these problems and ensure that the governor lube oil is kept clean, and to bring the AOE-3 and -4 governor maintenance in line with that of other AOE-1 Class ships, the following changes are recommended for MIP E-36/11-AO:

- Include steps on MRC AO-Q32S-N (R-1W) to sample and inspect the governor lube oil, and renew that lube oil when necessary.
- Change PMS task 18M-3R to S-( )R.

SARP Review

Four of six SARPs reviewed indicated that all the governors installed received class B overhauls. The two remaining SARPs indicated that some of the installed governors received class B overhauls and some received class C repairs. The majority of governors have received class B overhauls during shipyard periods.

The governors which received class C repairs during overhauls have experienced approximately eight times more significant maintenance actions than the governors receiving class B overhauls during the first 18 months after overhaul. Therefore, it is recommended that the LCHS turbine governors receive class B overhauls during future shipyard availabilities.

One of the AOE-1 Class ships has operated more than four years between overhauls without reporting significant LCHS pump unavailability during the intracycle. The MDS data indicates that the other ships could perform as well during the intracycle if allowed to operate for the same amount of time. Therefore, the recommended frequency for governor overhauls is 55 months. This task required an average of 20 man-days per governor.

The turbines received shipyard repairs similar to those of the governors. The significant turbine maintenance actions were reported sporadically throughout the MDS data period. The LCHS pumps were rarely reported

as unavailable because of turbine malfunctions. There was little difference between the intracycle performance of the turbines that received class B overhauls and those that received class C repairs. The data did not indicate that any noticeable benefit was gained by performing class B overhaul of the LCHS turbines; they should be repaired only as needed. Class C repairs during each ROH should adequately prepare the LCHS turbines for intrcycle operation. The specific repairs to be accomplished should be identified by performance tests and visual inspections as specified by PMS. It is estimated that these repairs will require 30 shipyard man-days per LCHS turbine.

Turbine repairs and inspections should include the following items as minimum requirements:

- Test combination exhaust and relief valve and repair as necessary
- Inspect/measure turbine thrust and journal bearings and repair as necessary
- Inspect turbine interior and turbine shaft packing and repair as necessary
- Clean lube oil sump, clean lube oil cooler, and renew oil
- Inspect and clean steam strainer
- Clean, inspect, and preserve exterior of turbine casing and base
- Ensure that all piping to the turbine is properly aligned

A task frequency of 55 months is selected, because one ship has operated for that length of time without major turbine problems and the data indicate that the other ships could also perform satisfactorily if allowed to operate for 55 months.

#### 3.2.1.2 Conclusions

The LCHS turbines have required little outside assistance during the intracycle. Review of the data and ship's force interviews indicate that ship's force can adequately maintain the turbines.

The LCHS turbines will require only class C repairs every 55 months to prepare adequately for the intracycle.

The control elements, specifically the governor and its associated components, have sometimes required large expenditures of ship's force man-hours and occasional IMA assistance. Adequate personnel training and greater emphasis on governor lube oil cleanliness are expected to reduce future corrective maintenance man-hours.

The LCHS turbine governors will require class B overhauls every 55 months to ensure proper intracycle performance.

#### 3.2.1.3 Recommendations

Review of the LCHS turbine maintenance data resulted in the following recommendations:

- Reserve 60 IMA man-hours every 2.5 years to flush, chemically clean, and repair three lube oil coolers (AOE-1 and -2 only).
- Change task Q-3 of MIP E-36/8-AO to Q-3R and add a note to accomplish this task every quarter and when directed as a result of lube oil inspection (R-1)
- Make the following changes to MIP E-36/11-AO:
  - Add "and daily when operating" to the note of task R-1W
  - Change PMS task 18M-3R to S-( )R
  - Include steps on MRC AO-Q32S-N(R-1W) to sample and inspect the governor lube oil and renew that lube oil when necessary
- Class B overhaul the LCHS turbine governors every 55 months
- Accomplish class C repairs, as indicated by performance tests and inspections, to the LCHS turbines every 55 months

### 3.2.2 Valves

#### 3.2.2.1 Discussion

Valve maintenance accounted for approximately 26 percent of the total LCHS maintenance burden. An average of 127.4 maintenance man-hours per ship operating year were reported for valve maintenance (see Table 3-1).

Table 3-4 summarizes the valve-related maintenance man-hours by ship class. Review of this table indicates that the AOR-1 Class ships perform more valve maintenance than the AOE-1 Class ships.

*Table 3-4.* LCHS MAN-HOUR SUMMARY: VALVES

| Ship Class | Maintenance Man-Hours | | | Maintenance Man-Hours per Ship Operating Year | | |
|---|---|---|---|---|---|---|
| | Ship's Force | IMA | Total | Ship's Force | IMA | Total |
| AOE-1 | 1,528 | 427 | 1,955 | 72.2 | 20.2 | 92.4 |
| AOR-1 | 4,061 | 1,301 | 5,362 | 111.9 | 35.8 | 147.7 |

## Valve Maintenance

Examination of the MDS narratives indicated the following:

- No individual valve (one APL) is responsible for a significant portion of the total ship class valve maintenance burden, but all the valves collectively account for a significant maintenance burden.
- The most commonly reported failure modes were the following:
  - Valve seal leaks
  - Valve does not open or close
  - Valve stem leaks or is bent
  - Valve internals worn
  - Valve is not set properly (relief/exhaust valves)
- Most valve maintenance problems can be corrected by ship's force personnel with little outside assistance.
- Small (less than three IPS) general purpose valves are routinely replaced as required by ship's force.
- As the size (IPS) of the valves increased, the number of maintenance man-hours required to accomplish routine repairs also increased.
- Valve maintenance was most often deferred for the following reasons:
  - Ship's force work backlog or operational priority
  - Lack of facilities or capabilities
- Supply support for valves is adequate.

Interviews with ship's force personnel indicate that some valves require large expenditures of maintenance effort for routine repairs. These valves either are located in or on liquid cargo storage tanks or have one side open to the sea. Often valves located in or on tanks could not be repaired because the tanks were full of oil. If or when the oil could be off-loaded or moved to a safe tank, the tank had to be partially cleaned and certified gas-free before the needed repairs could be accomplished. Reported expenditures of 60 to 100 man-hours were common for these repairs. Sea valves require either ship drydocking or the installation of coffer dams before valve repairs are made. Most of the time these hard-to-get-to valves were left for repair during overhauls.

IMAs overhauled those valves which could be easily removed from the system. The need for valve overhauls was nearly constant throughout ship intracycles. The many valves repaired by the IMAs were of no particular size or type. It is anticipated that the need for valve repairs will continue during future intracycles; therefore, it is recommended that IMA

man-hours be reserved for the general valve repairs. Approximately one-third of the maintenance actions requesting outside assistance were reported complete. IMA man-hour expenditures may thus be approximated by tripling the reported annual IMA man-hour expenditures in Table 3-4. The following IMA man-hour reservations for valve repairs are recommended:

- AOE-1 Class ships -- 60 man-hours per ship per year
- AOR-1 Class ships -- 110 man-hours per ship per year

SARP Review

Review of the available SARPs indicates that some valves (5 to 24 IPS) receive class B overhauls during shipyard availabilities, while others are simply repaired. As few as 40 and as many as 135 valves of various sizes have received class B overhauls during shipyard availabilities. The exact locations and uses of the valves overhauled could not be determined from review of the SARPs. It is recommended that a study be initiated to identify the following valves for these ship classes:

- All valves located in or on fuel oil tanks that require an associated fuel oil tank to be emptied and certified gas-free prior to hot work on the valves
- All valves that open to the sea
- All valves 18 IPS or larger

The valves identified in this study should receive class B overhauls during every regular overhaul to ensure their availability during the intracycle and to reduce the anticipated ship's force and IMA maintenance burden that will result if they are not overhauled.

Review of the available SARPs indicates that AOE-1 Class LCHS valve overhauls have accounted for as few as 514 shipyard man-days and as many as 2,150 man-days, and that AOR-1 Class LCHS valve overhauls have ranged from 795 man-days to 1,780 man-days. It is estimated that the overhaul of the valves identified by the study will require 1,300 man-days for AOE-1 and AOR-1 Class ships (approximately the middle of each range). It is recommended that this man-hour estimate be reevaluated following completion of the study discussed above.

The remaining general purpose LCHS valves should be repaired as necessary during each ROH but not overhauled, because they can usually be easily repaired during the intracycle by ship's force and IMAs. It is anticipated that these repairs, including some class B overhauls and some class C repairs, will require approximately 400 shipyard man-days for AOE-1 and AOR-1 Class ships. These man-days should be reserved for all AOE-1 and AOR-1 regular overhauls.

Special-purpose LCHS relief valves or dual-purpose exhaust/relief valves are routinely tested, repaired, and reset during regular overhauls. Interviews with ship's force personnel and review of the MDS data indicate

that ship's force personnel cannot reset these valves; they are usually reset by the IMAs during the intracycle. This intracycle maintenance burden has been relatively small -- less than 5 man-hours per year. It is recommended that these valves continue to be overhauled during regular overhauls so that the intracycle maintenance for relief valves does not increase. This task has required approximately 65 man-days for AOR-1 Class ships and 75 man-days for AOE-1 Class ships.

#### 3.2.2.2 Recommendations

The recommendations resulting from this review of the LCHS valves maintenance data are as follows:

- IMA should continue to repair/overhaul valves on an as-needed basis during the intracycle:
  - AOE-1 Class ships - 60 man-hours per ship per year
  - AOR-1 Class ships - 110 man-hours per ship per year
- A study should be initiated to identify the following valves:
  - All valves located in or on fuel oil tanks that require an associated fuel oil tank to be emptied and certified gas-free prior to hot work on the valves.
  - All valves that open to the sea
  - All valves 18 IPS or larger
- The valves identified in the proposed study should receive class B overhaul at every ROH (1,300 man-days for AOE-1 and AOR-1 Class ships).
- The remaining general purpose LCHS valves should be repaired as necessary at every ROH (400 man-days for AOE-1 and AOR-1 Class ships).
- All LCHS relief valves and dual-purpose exhaust/relief valves should be overhauled and reset at every ROH:
  - AOE-1 Class ships - 75 man-days
  - AOR-1 Class ships - 65 man-days

### 3.2.3 Pumps

#### 3.2.3.1 Discussion

The MDS maintenance data reported against the LCHS pumps accounted for approximately 16 percent of the total LCHS maintenance burden. Approximately 52 percent of the LCHS CASREPs were reported against various pumps (see Appendix D).

Table 3-5 summarizes the ship's force and IMA man-hours reported for the maintenance of specific components of the LCHS pumps. The data are further broken down by hull or hull group with identical pump configurations

*Table 3-5.* LCHS MAN-HOUR SUMMARY: PUMPS

| Component | Maintenance Man-Hours | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AOE-1 | | AOE-2 | | AOE-3 and -4 | | AOR-1 through -6 | | AOR-7 | | All Hulls | |
| | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA |
| 1. Pump | | | | | | | | | | | | |
| a. Mechanical seals | 2 | 0 | 8 | 0 | 83 | 0 | 388 | 546 | 4 | 0 | 485 | 546 |
| b. Shaft | 0 | 0 | 0 | 0 | 16 | 0 | 159 | 2 | 0 | 0 | 175 | 2 |
| c. Wearing rings | 0 | 0 | 173 | 237 | 0 | 0 | 72 | 0 | 0 | 0 | 245 | 237 |
| d. Bearings | 0 | 0 | 0 | 0 | 5 | 0 | 64 | 0 | 0 | 0 | 69 | 0 |
| e. Rotating element | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 21 | 0 |
| f. Casing | 0 | 0 | 0 | 0 | 0 | 0 | 120 | 45 | 0 | 0 | 120 | 45 |
| g. Base studs | 0 | 0 | 0 | 0 | 20 | 0 | 2 | 0 | 0 | 0 | 22 | 0 |
| h. Relief valves | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 18 | 0 |
| i. Other | 3 | 0 | 59 | 23 | 569 | 0 | 1,332 | 181 | 2 | 0 | 1,965 | 204 |
| Subtotal | 5 | 0 | 240 | 260 | 693 | 0 | 2,176 | 774 | 6 | 0 | 3,120 | 1,034 |
| 2. Couplings | 0 | 0 | 0 | 0 | 115 | 0 | 20 | 0 | 0 | 0 | 135 | 0 |
| 3. Other | 54 | 0 | 4 | 1 | 160 | 0 | 82 | 25 | 0 | 0 | 300 | 26 |
| Total | 59 | 0 | 244 | 261 | 968 | 0 | 2.278 | 799 | 6 | 0 | 3,555 | 1,060 |

(pumps with the same APL). Nonrepetitive repairs and repairs involving more than one component have been grouped into the "Other" categories.

Table 3-6 presents the man-hour summary data (data provided in Table 3-5), distributed by the ship or ship group operating years. The data shown are the average number of maintenance man-hours per ship operating year reported for the respective pump components.

Table 3-6 indicates that most repetitive pump repairs are accomplished by ship's force personnel with little or no outside assistance. Some ships or ship groups have experienced particular maintenance problems more than other ships. AOE-2 has reported excessive wearing ring repairs. AOR-1 through -6 have reported approximately 3.7 times more mechanical seal maintenance man-hours than any other ship group examined. AOE-3 and -4 and AOR-1 through -6 reported at least 3.7 more "Other" maintenance man-hours (usually pump overhauls) than any other ship groups. These apparent maintenance differences are discussed in the following subsections.

### Mechanical Seal Maintenance

AOR-1 through -6 reported a total of 388 ship's force man-hours and 546 IMA man-hours for mechanical seal maintenance (see Table 3-5), which accounted for approximately 11.9 ship's force man-hours and 16.8 IMA man-hours per ship operating year. The mechanical seal maintenance reported was always that seals began to leak and were replaced. A total of 26 seals were replaced during the 32.6-ship-operating-year data period. The AOR-1 through -6 ships replaced one mechanical seal every 1.3 years.

The on-board allowance for the mechanical seals is more than adequate to support the present usage rate.

The maintenance actions citing the need for mechanical seal replacement indicated the following:

- Approximately 87 percent were discovered during PMS
- The reported status was always 1 - Operational
- The reported cause was always 7 - Normal Wear and Tear
- These maintenance actions were deferred for the following reasons:
  - 1 (Ship's force work backlog/operational priority) -- 53 percent
  - 6 (Lack of facilities/capabilities) -- 47 percent
- Of the maintenance actions reporting an IMA response, 78 percent indicated that the IMAs rejected the request because of excessive shop workload or insufficient availability and 22 percent indicated that maintenance was completed by using parts.
- When maintenance was completed by ship's force without IMA assistance, approximately 12 ship's force man-hours were reported.

*Table 3-6.* LCHS PUMP MAN-HOUR SUMMARY NORMALIZED TO SHIP OPERATING YEAR

| Component | Average Maintenance Man-Hours per Component Group per Ship Operating Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AOE-1 | | AOE-2 | | AOE-3 and -4 | | AOR-1 through -6 | | AOR-7 | | All Hulls | |
| | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA |
| 1. Pump | | | | | | | | | | | | |
| a. Mechanical seals | 0.4 | 0 | 1.4 | 0.0 | 7.8 | 0 | 11.9 | 16.8 | 1.0 | 0 | 8.4 | 9.5 |
| b. Shaft | 0.0 | 0 | 0.0 | 0.0 | 1.5 | 0 | 4.9 | 0.1 | 0.0 | 0 | 3.0 | 0.0 |
| c. Wearing rings | 0.0 | 0 | 30.7 | 42.0 | 0.0 | 0 | 2.2 | 0.0 | 0.0 | 0 | 4.3 | 4.1 |
| d. Bearings | 0.0 | 0 | 0.0 | 0.0 | 0.5 | 0 | 1.9 | 0.0 | 0.0 | 0 | 1.2 | 0.0 |
| e. Rotating element | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0 | 0.6 | 0.0 | 0.0 | 0 | 0.4 | 0.0 |
| f. Casing | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0 | 3.7 | 1.4 | 0.0 | 0 | 2.1 | 0.8 |
| g. Base studs | 0.0 | 0 | 0.0 | 0.0 | 1.9 | 0 | 0.1 | 0.0 | 0.0 | 0 | 0.4 | 0.0 |
| h. Relief valves | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0 | 0.6 | 0.0 | 0.0 | 0 | 0.3 | 0.0 |
| i. Other | 0.6 | 0 | 10.5 | 4.1 | 53.7 | 0 | 40.9 | 5.6 | 0.5 | 0 | 34.2 | 3.6 |
| Subtotal | 1.0 | 0 | 42.5 | 46.1 | 65.4 | 0 | 66.8 | 23.8 | 1.6 | 0 | 54.3 | 17.9 |
| 2. Couplings | 0.0 | 0 | 0.0 | 0.0 | 10.8 | 0 | 0.6 | 0.0 | 0.0 | 0 | 2.3 | 0.0 |
| 3. Other | 10.9 | 0 | 0.7 | 0.2 | 15.1 | 0 | 2.5 | 0.8 | 0.0 | 0 | 5.2 | 0.4 |
| Total | 11.9 | 0 | 43.3 | 46.3 | 91.4 | 0 | 69.9 | 24.5 | 1.6 | 0 | 61.9 | 18.4 |

- When maintenance was completed by ship's force with IMA assistance, an average 66 ship's force man-hours and 267 IMA man-hours were reported for each maintenance action. (One maintenance action reported 487 IMA man-hours.)

It is believed that when IMA assistance was given, other pump repairs were also accomplished. Since the data and shipboard interviews indicate that ship's force personnel are able to replace the mechanical seals when needed, IMA man-hours need not be reserved during the operating cycle for these repairs.

Wearing Ring Repairs

AOE-2 reported an average of 30.7 ship's force man-hours and 42 IMA man-hours for pump wearing ring repairs (see Table 3-6). More than 90 percent of the total ship's force or IMA man-hours reported for this maintenance action were reported in 1975. The remaining 18 maintenance man-hours were reported in 1976. This type of maintenance action has not been reported again, and so it is concluded that this problem no longer exists.

It is believed that this problem may have developed because of the extended operating cycle of AOE-2 and the inability of ship's force personnel to easily accomplish major cargo pump repairs. The AOE-2 had been operational for more than four years when this maintenance requirement was identified for the first time. Interviews with ship's force personnel indicate that they cannot easily accomplish major pump repairs without outside assistance because of the great size and weight of the cargo pumps. The six maintenance actions reported for this failure mode all indicated that the needed wearing ring repairs or replacements were the result of normal equipment wear rather than the result of poor design or operational error. Five of nine pumps installed were reported for worn out wearing rings. AOE-2 entered ROH shortly after the last report of this problem. On the basis of these reports, it is concluded that these pumps should be repaired before equipment wearout causes reduced equipment capability or unavailability, i.e., before four years have elapsed.

Other Pump Maintenance

AOE-3 and -4 and AOR-1 through -6 reported a total of 1,930 ship's force man-hours and 480 IMA man-hours for LCHS pump maintenance involving both multiple pump component repairs and nonrepetitive repairs. The MDS narratives indicated that most of these maintenance man-hours were used when pump clearances had exceeded their maximum or when "pump overhauls" had to be performed. These maintenance actions usually included the following repairs:

- Replace mechanical seals and gaskets
- Replace casing and impeller wearing rings
- Replace shaft sleeves
- Check shaft for trueness

- Replace bearings
- Balance rotor
- Replace packing and fasteners

The repairs actually accomplished could not be determined from the narratives. Ship's force interviews indicate that replacing the wearing rings, checking the shaft for trueness, or balancing a rotor are extremely difficult or impossible for ship's force personnel to accomplish.

Ship's force personnel reported an average of 93 ship's force man-hours per maintenance action to complete whatever necessary repairs they were able to accomplish. When IMA assistance was reported, an average 75 IMA man-hours were reported per maintenance action.

All of these maintenance actions requested outside assistance, usually because of lack of facilities or capability. Approximately 60.9 percent of these maintenance actions indicated a pump status of "reduced capability," while approximately 21.7 percent indicated a status of "nonoperational."

These maintenance actions were most often reported during the fourth and fifth years after overhaul. Approximately 73.9 percent of these maintenance actions were reported during the fourth and fifth years after overhaul (fourth year - 21.7 percent, fifth year - 52.2 percent). These facts and the reported wearing ring maintenance experience discussed earlier indicate that the LCHS cargo pumps are experiencing significantly more wear-related problems during the fourth and fifth operational years than during previous years.

### SARP Review

Review of the available AOE-1 and AOR-1 Class SARPs indicated that the LCHS pumps usually received class B overhauls during shipyard availabilities ( 8 of 9 SARPs). This information and the data presented above indicate that class B overhauls improve the performance and therefore the availability of these pumps. It is concluded that class B overhauls should be accomplished on the LCHS pumps during shipyard availabilities. These overhauls should include as a minimum the following actions:

- Disassemble pumps
- Check shaft for trueness
- Install new casing and impeller wearing rings
- Install new shaft sleeves
- Install new bearings, packing, and seals
- Balance rotating units
- Reassemble pumps using new gaskets and fasteners
- Realign piping to unit
- Perform operational test

The actions listed above were the most commonly reported in the SARPs reviewed.

This task required an average of 10 shipyard man-days for stripping pumps and 43 shipyard man-days for cargo pumps. The larger pumps (6,000 gpm) installed on AOE-3 and -4 will require 46 man-days per pump.

CASREP Review

Review of the reported CASREPs (see Table D-1 of Appendix D) indicates the following:

- There were no significant repetitive pump CASREPs.
- Most wear-related casualties were reported during the fourth and fifth years after regular overhauls.
- Parts support is adequate (no downtime due to supply was reported for any LCHS cargo pumps).
- Downtime man-hours due to maintenance averaged 1,972.4 man-hours (total 27,614 maintenance man-hours) per CASREP.
- Only one ship reported two or more LCHS pump CASREPs during the same period.

### 3.2.3.2 Conclusions

The CASREP and MDS data indicate that the LCHS pumps show more signs of wear as the operating time increases. The pumps usually do not fail catastrophically, but instead exhibit less and less pumping capacity as time since last overhaul increases. The data also indicate that only once were enough pumps down concurrently to prohibit the full operation of four stations, supplying both JP-5 and DFM (AOE-2 during the fifth operational year). Therefore, it is concluded that the LCHS pumps should receive class B overhauls every four years to prevent wear-related pump failures. It is anticipated that the number of pump failures that occur before overhaul will not be great enough to degrade the LCHS system below minimum needs.

### 3.2.3.3 Recommendations

The LCHS pumps should receive class B overhauls every four years, including as a minimum the following actions:

- Disassemble pumps
- Check shaft for trueness
- Install new casing and impeller wearing rings
- Install new shaft sleeves
- Install new bearings, packing, and seals
- Balance rotating units

- Reassemble pumps using new gaskets and fasteners
- Realign piping to unit
- Perform operational test

### 3.2.4 Controls and Indicators

#### 3.2.4.1 Discussion

AOE-1 and AOR-1 Class ships reported a total of 2,000 ship's force man-hours and 900 IMA man-hours for the maintenance of the LCHS controls and indicators. This maintenance burden accounts for approximately 11 percent of the LCHS ship's force maintenance man-hours and 9 percent of the LCHS IMA maintenance man-hours. Table 3-7 presents a man-hour summary of the failure mode or component problems for each type of LCHS indicator. When a specific type of indicator could not be identified, the maintenance man-hours were grouped into general categories of Indicators, Meters, or Gauges (type unspecified). The average maintenance man-hours for each component group and each ship class are also shown in Table 3-7.

On-Board Capability

Table 3-7 indicates that the AOE-1 Class ships require approximately three times as much indicator maintenance as the AOR-1 Class ships. This significant difference in the two ship class maintenance experiences results from the different class designs and the fact that AOR-1 Class ships have some on-board capability to calibrate nonelectric gauges and meters.

The LCHS indicators that cannot be calibrated on board must be deferred to an IMA or shipyard facility for calibration and repair. These indicators are routinely calibrated and repaired by the IMAs as necessary. Scheduling of these repairs and calibrations is managed through the Metrology Automated System for Uniform Recall and Reporting (MEASURE) Program. This program is designed to provide participating activities with a standard system for scheduling test, measurement, and diagnostic equipment (TMDE) for recall and calibration at designated facilities, and for documenting the data pertaining to calibration and repair actions performed by these facilities. All AOE-1 and AOR-1 Class ships have implemented the MEASURE Program; therefore, these repairs and calibrations need not be scheduled through other maintenance programs.

Ship's forces report that the MEASURE Program is basically sound. Problems arise only when the program is not given adequate attention. The MEASURE Program is generally given a very low priority by fleet personnel, because of immediate corrective maintenance problems and reported personnel shortages.

Indicator Requirements

Approximately one in three maintenance actions requesting an IMA to calibrate or repair some type of indicator was acted upon by the IMAs.

Table 3-7. MAINTENANCE MAN-HOUR SUMMARY FOR CONTROLS/INDICATORS

| Failure Mode or Problem by Component Group | Component Maintenance Man-Hours | | | | | | Average Maintenance Man-Hours per Component Group per Ship Operating Year | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AOE-1 Class | | AOR-1 Class | | All Hulls | | AOE-1 Class | | AOR-1 Class | | All Hulls | |
| | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA |
| 1. Tank Level Indicators | | | | | | | | | | | | |
| a. Needs repair and calibration | 377 | 390 | 147 | 44 | 524 | 434 | 17.8 | 18.4 | 4.0 | 1.2 | 9.1 | 7.6 |
| b. Transmitter inoperable | 5 | 0 | 10 | 0 | 15 | 0 | 0.2 | 0.0 | 0.3 | 0.0 | 0.3 | 0.0 |
| c. Grounded | 0 | 0 | 61 | 0 | 61 | 0 | 0.0 | 0.0 | 1.7 | 0.0 | 1.1 | 0.0 |
| d. Alarm inaudible | 3 | 0 | 0 | 0 | 3 | 0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| e. Missing/installation incomplete | 31 | 0 | 36 | 0 | 67 | 0 | 1.5 | 0.0 | 0.9 | 0.0 | 1.2 | 0.0 |
| f. Broken wires | 2 | 0 | 69 | 15 | 71 | 15 | 0.1 | 0.0 | 1.9 | 0.4 | 1.2 | 0.3 |
| g. Power supply inoperable | 15 | 3 | 11 | 0 | 26 | 3 | 0.7 | 0.1 | 0.3 | 0.0 | 0.4 | 0.1 |
| Subtotal | 433 | 393 | 334 | 59 | 767 | 452 | 20.5 | 18.6 | 9.2 | 1.6 | 13.4 | 7.9 |
| 2. Valve Position Indicators | | | | | | | | | | | | |
| a. Hydraulic leaks | 0 | 0 | 24 | 0 | 24 | 0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.4 | 0.0 |
| b. Deteriorated switches | 0 | 0 | 1 | 48 | 1 | 48 | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 | 0.8 |
| c. Needs repair | 331 | 0 | 98 | 0 | 429 | 0 | 15.6 | 0.0 | 2.7 | 0.0 | 7.5 | 0.0 |
| Subtotal | 331 | 0 | 123 | 48 | 454 | 48 | 15.6 | 0.0 | 3.4 | 1.3 | 7.9 | 0.8 |
| 3. Indicators (type unspecified) | 0 | 0 | 0 | 20 | 0 | 20 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.3 |
| 4. **Flowmeters** | | | | | | | | | | | | |
| **Needs repair and calibration** | 0 | 0 | 8 | 34 | 8 | 34 | 0.0 | 0.0 | 0.2 | 0.9 | 0.1 | 0.6 |
| 5. **Tachometers** | | | | | | | | | | | | |
| **Needs repair and calibration** | 106 | 131 | 0 | 0 | 106 | 131 | 5.0 | 6.2 | 0.0 | 0.0 | * | * |
| 6. **Thermometers** | | | | | | | | | | | | |
| a. **Needs repair and calibration** | 72 | 9 | 0 | 0 | 72 | 9 | 3.4 | 0.4 | 0.0 | 0.0 | * | * |
| b. **Broken** | 8 | 0 | 0 | 0 | 8 | 0 | 0.4 | 0.0 | 0.0 | 0.0 | * | * |
| Subtotal | 80 | 9 | 0 | 0 | 80 | 9 | 3.8 | 0.4 | 0.0 | 0.0 | | |

(continued)

*Table 3-7.* (continued)

| Failure Mode or Problem by Component Group | Component Maintenance Man-Hours | | | | | | Average Maintenance Man-Hours per Component Group per Ship Operating Year | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AOE-1 Class | | AOR-1 Class | | All Hulls | | AOE-1 Class | | AOR-1 Class | | All Hulls | |
| | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA | Ship's Force | IMA |
| 7. Meters (type unspecified) | | | | | | | | | | | | |
| a. Needs repair and calibration | 8 | 0 | 7 | 0 | 15 | 0 | 0.4 | 0.0 | 0.2 | 0.0 | 0.3 | 0.0 |
| b. Need installed/replaced | 24 | 0 | 61 | 0 | 85 | 0 | 1.1 | 0.0 | 1.7 | 0.0 | 1.5 | 0.0 |
| c. Need to be removed | 6 | 1 | 0 | 0 | 6 | 1 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| d. Rusted | 20 | 0 | 0 | 0 | 20 | 0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| Subtotal | 58 | 1 | 68 | 0 | 126 | 1 | 2.7 | 0.0 | 1.9 | 0.0 | 2.2 | 0.0 |
| 8. Gauges (type unspecified) | | | | | | | | | | | | |
| Need repair and calibration | 184 | 28 | 264 | 153 | 448 | 181 | 8.7 | 1.3 | 7.3 | 4.2 | 7.8 | 3.2 |
| 9. Pump Centering Gages | | | | | | | | | | | | |
| Not carried | 23** | 299** | 0 | 0 | 23** | 299** | 1.1 | 14.1 | 0.0 | 0.0 | * | * |
| 10. Sight Glass | | | | | | | | | | | | |
| a. Valve stem broken | 3 | 24 | 0 | 0 | 3 | 24 | 0.1 | 1.1 | 0.0 | 0.0 | 0.1 | 0.4 |
| b. Cracked | 5 | 0 | 3 | 0 | 8 | 0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 |
| Subtotal | 8 | 24 | 3 | 0 | 11 | 24 | 0.4 | 1.1 | 0.1 | 0.0 | 0.2 | 0.4 |
| Total | 1,200 | 566 | 800 | 314 | 2,000 | 900 | 56.7 | 27.7 | 22.0 | 8.6 | 34.8 | 15.7 |

*Component group installed or reported by only one ship class. Average maintenance man-hours per component group ship operating year not computed.

**Man-hours not included in class totals because this maintenance action (1) is unusual and will probably not occur again.

Therefore, an average number of IMA man-hours required for indicator calibration and repair during one operating year can be approximated by tripling the respective class total average IMA maintenance man-hours per ship operating year shown in Table 3-7. Since the need for indicator repairs and calibrations is expected to continue during future intracycles, it is recommended that the following IMA man-hour reservations be adopted to plan for annual indicator repairs and calibration:

- AOE-1 Class ships - 85 IMA man-hours per year
- AOR-1 Class ships - 30 IMA man-hours per year

Review of the available AOE-1 and AOR-1 Class SARPs shows that indicator repairs and calibration are routinely accomplished during all shipyard availabilities. The average shipyard man-day expenditures reported were 40 man-days for AOE-1 Class ships and 24 man-days for AOR-1 Class ships.

Ship's force personnel reported that there was never a time when all of the installed LCHS indicators were completely operational, even immediately following regular overhauls.

The primary purpose of the indicators is to allow the equipment operators to monitor the operation of the major LCHS components. Proper monitoring enables the technicians to evaluate the material condition of operating equipments continually and thereby correct minor system degradation as it occurs. The timely correction of minor degradation helps prevent the occurrence of serious casualties and therefore increases equipment availability. For these reasons, more attention should be given to LCHS indicators (including all LCHS meters, gauges, sight glasses, and light indicators) during regular ship overhauls. It is recommended that all LCHS indicators be verified operational during all shipyard availabilities. It is estimated that this task will require 55 man-days for AOE-1 Class ships and 40 man-days for AOR-1 Class ships.

### 3.2.4.2 Recommendations

The recommendations resulting from review of the LCHS indicator maintenance data are as follows:

- Adopt the following IMA man-hour reservations for annual indicator repairs and calibration:
  - AOE-1 Class ships - 85 IMA man-hours
  - AOR-1 Class ships - 30 IMA man-hours
- Verify the operation of all LCHS indicators (including all LCHS meters, gauges, sight glasses, and light indicators) and repair and calibrate as necessary each regular overhaul.

### 3.2.5 Actuators

#### 3.2.5.1 Discussion

Actuators include all LCHS robot arms and hydraulic actuating equipment.

Actuators accounted for a total of 987 maintenance man-hours, or 17.2 maintenance man-hours per ship operating year, a maintenance burden of approximately 3.5 percent of the total LCHS burden. Only 48 IMA maintenance man-hours were reported for actuators, an average of approximately 0.8 IMA man-hour per ship operating year. This is not a sufficient number of annual man-hours to warrant annual IMA maintenance planning.

##### MDS Review

The MDS data indicate that these hydraulic components experience intermittent leaking problems more often than any other failure. When leaking occurs, ship's force personnel will either replace the seals or defer the maintenance because the actuator is in or on a liquid cargo fuel oil tank that would have to be emptied prior to seal replacement. Generally, ship's force personnel are able to make these repairs once they have access to the components. No other repetitive failure modes were identified.

##### SARP Review

Review of the available SARPs indicates that the hydraulic valve actuators sometimes received class C repairs (averaging 15 man-days), and sometimes received class B overhauls (as many as 1,500 shipyard man-days). It was not possible to identify the actuators that were repaired during the availabilities. The equipment maintenance histories reported in MDS and CASREP data following either class C repairs or class B overhauls indicated that there were no major maintenance differences. Therefore, routine class B overhaul of all valve actuators is not warranted.

It is recommended that these actuators receive class C repairs during every ROH. It is estimated that this task will require 30 shipyard man-days.

#### 3.2.5.2 Recommendation

The recommendation resulting from this review of the LCHS actuator maintenance data is to accomplish class C repairs to all hydraulic actuators during every ROH (AOE-1 and AOR-1 Classes - 30 man-days).

### 3.2.6 Motors

#### 3.2.6.1 Discussion

Relatively few maintenance man-hours were reported against the LCHS motors (all AOR-1 Class cargo pumps are motor-driven). A total of 344 maintenance man-hours were reported by all AOE-1 and AOR-1 Class ships. AOE-1 Class ships reported an average of 6.4 man-hours per ship operating year, while AOR-1 Class ships reported an average of 5.7 man-hours per ship operating year for motor repairs.

### Intracycle Maintenance

The MDS data reported for the LCHS motors indicate that very few motor problems were reported. Technicians occasionally reported worn bearings, worn contacts, or dirty windings. Most of these maintenance actions were completed by ship's force personnel without IMA assistance. Three maintenance transactions reported IMA man-hours.

The majority of the motor-related maintenance actions were reported during the third and fourth years after overhaul. Only one maintenance action for LCHS motors was reported within two years after a regular overhaul. Almost half the motor maintenance actions in the MDS data base were reported completed during the respective ship's regular overhaul.

No CASREPs were reported for motor failures.

### SARP Review

Review of the available SARPs indicates that the LCHS motors (including cargo pump motors and controllers, and stripping pump motors and controllers) always receive class B overhauls during shipyard availabilities. These overhauls required an average of 6 man-days per AOR-1 Class stripping pump motor and controller, 12 man-days per AOR-1 Class cargo pump motor and controller, and 8 man-days per AOE-1 Class stripping pump motor and controller.

In view of the maintenance history of the LCHS motors, it is recommended that the practice of class B overhauling cargo and stripping pump motors and controllers be continued.

### 3.2.6.2 Recommendations

The recommendations resulting from this review of the LCHS motor maintenance data is to class B overhaul all LCHS cargo and stripping pump motors every regular overhaul:

- AOR-1 Class stripping pump - 6 man-days per motor and associated controller
- AOR-1 Class cargo pump - 12 man-days per motor and associated controller
- AOE-1 Class stripping pump - 8 man-days per motor and associated controller

## 3.2.7 Other System-Related Maintenance

### 3.2.7.1 Discussion

Maintenance actions that did not fall within any of the previously discussed categories were grouped in the category of "Other System-Related Maintenance." This maintenance required an average of 115 maintenance

man-hours per ship operating year. Typical maintenance actions in this category were the following:

- Clean and preserve tanks
- Replace missing/deteriorated flash screens
- Replace deteriorated fuel oil piping
- Replace sounding tube covers
- Replace flange shields
- Replace tank top guards
- Make fuel oil piping spools
- Manufacture monel bolts
- Manufacture instruction plates

Many of the maintenance actions listed above required IMA assistance. IMAs expended approximately 87 man-hours per ship operating year to accomplish these miscellaneous repairs. The majority of these individual maintenance actions do not occur often enough to warrant periodic maintenance planning. However, it is anticipated that many of the maintenance actions will reoccur unpredictably during future intracycles. It is recommended that IMAs reserve approximately 85 man-hours per combat support ship LCHS ship operating year to accomplish these miscellaneous repairs.

Some of the intracycle maintenance burden reported for the maintenance actions listed above could be eliminated or reduced if the LCHS pipes and tanks were periodically cleaned, inspected, and repaired.

Review of Naval ship technical manuals (NSTM) suggested that some LCHS subsystem tests and inspections should be accomplished during regular overhauls.

The following NSTMs were reviewed:

| Title | Old Number | New Number |
|---|---|---|
| Piping | 9480 | 505 |
| Hydraulic Equipment | 9210 | 556 |
| Gas and JP-5 Fuel Systems | 9150 | 542 |

The recommendations resulting from the reviews are discussed in subsequent paragraphs.

NSTM 9480 requires that all piping systems be hydrostatically tested to 135 percent of the system design pressure at intervals not to exceed five years, preferably before or during the early stages of a scheduled major overhaul of the ship.

NSTM 9150 lists requirements to test and flush the AVGAS and JP-5 systems. These tasks are to be accomplished when the systems are reactivated after ship overhauls, or when the systems have been repaired to such an extent that a check of the entire system is warranted. The tests include air and R-12 tests of the piping and storage tanks, hydrostatic tests of the system, and flushing of the system. Specific steps for the AVGAS and JP-5 systems are listed in paragraphs 9150.1.6.2 and 9150.2.6.2, respectively. These tests will identify all system leaks and thoroughly clean the piping.

It is recommended that these subsystem tests be accomplished during future ship overhauls. AVGAS subsystem tests should not be accomplished if Shipalt AOE-36B (remove AVGAS capability) has been or is being accomplished, or if action has been taken on reference A of COMNAVSEASYSCOM Washington, D.C., message date time group 231434ZJAN 81 (authorizes removal of external AVGAS piping).

Review of the available SARPs indicates that some or all of the fuel oil tanks are usually cleaned, tested, and repaired every shipyard availability, but that the LCHS piping subsystems are not routinely being tested and repaired as necessary. The routine performance of these tests would identify subsystem leaks and might reduce the intracycle maintenance workload for ship's force personnel and IMAs. The MDS data indicate that ship's force personnel reported 2,306 maintenance man-hours and IMAs reported 542 maintenance man-hours for LCHS piping subsystem repairs and cleaning.

Ship's force personnel report that there are very few times during the intracycle when a good subsystem cleaning and testing could be accomplished, because of the ship's operational pace and the regular LCHS usage.

PMS MIP A-17/116-20, task SU-1, also requires the testing and flushing of the JP-5 subsystem after system repairs or overhaul. The tank is to be tested and flushed in an industrial environment. It is estimated that this task, to include only the LCHS piping, will require 20 shipyard man-days per subsystem.

It is recommended that a qualified (Q) task be included in the AOE-1 and AOR-1 CMPs for repairs that result from the subsystem testing. It is estimated that this task will require 15 shipyard man-days.

NSTM 9210 requires the "hydrostatic" testing of hydraulic subsystems when components are disassembled or major repairs are accomplished. Test and safety procedures are as outlined in NSTM 9480, except that hydrostatic tests of installed systems shall be conducted with system fluid in lieu of fresh water. Like the previous tasks, this task might reduce intracycle ship's force and IMA maintenance; it will require a subsequent qualified task to accomplish the indicated repairs. It is estimated that these hydraulic subsystem tests will require five shipyard man-days and that the resultant repairs will require 10 man-days.

#### 3.2.7.2 Conclusions

Many miscellaneous LCHS repairs are reported during the intracycles. Each repair or failure mode, examined individually, does not occur often enough to warrant the planning of periodic maintenance; however, the combination of these repairs accounts for a substantial part of the maintenance reported for the LCHS.

#### 3.2.7.3 Recommendations

IMAs should plan to expend approximately 85 man-hours per combat support ship LCHS ship operating year to accomplish miscellaneous system repairs. The following tasks should be accomplished each regular overhaul:

- LCHS subsystem tests in accordance with NSTM 9150 (do not accomplish AVGAS subsystem tests if AVGAS capability has been removed) -- 20 man-days per subsystem
- LCHS subsystem repairs that result from subsystem tests -- 15 man-days per subsystem
- LCHS hydraulic subsystem "hydrostatic tests" in accordance with NSTM 9210 and NSTM 9480 -- 5 man-days
- LCHS hydraulic subsystem repairs that result from hydraulic system tests -- 10 man-days

## 3.3 MAINTENANCE STRATEGY

Results of the analysis indicate that the entire LCHS need not be overhauled to prepare for the operating cycle. The LCHS cargo and stripping pumps, motors and associated controllers, turbine governors, and relief and hard-to-get-at valves will require class B overhauls to ensure satisfactory intracycle performance. The other LCHS components need only be cleaned, tested, and repaired as necessary before the operating cycle begins.

Determination of how long the LCHS can operate between required depot-level repairs is limited by the anticipated wearout of the LCHS pumps during the fourth operational year. Indications are that the other major LCHS components could operate satisfactorily for more than four years. It is anticipated that the overhaul of the LCHS pumps after four years of operation will ensure 100 percent or greater subsystem availability during the intracycle (described in Section 3.1). Longer pump overhaul intervals will degrade LCHS subsystem availability.

AOE-3 and -4 have greater DFM and JP-5 pumping capacities than the other combat support ships. Therefore, more pumps could be degraded or lost on these ships and still provide fuel oil at 100 percent of the receiving capacities of other fleet ships. It is anticipated that AOE-3 and -4 pump overhaul frequencies could be safely extended to five years without subsystem degradation below the minimums established in Section 3.1 of this report. Such action is recommended for these two ships.

The remaining combat support ships could sustain intracycle LCHS pump operation of more than four years if the planning activities are willing to accept lower subsystem availabilities than those established in Section 3.1.

When the LCHS pumps are overhauled, it would be prudent to overhaul and repair the other LCHS components as well. This practice will enable the combat support ship LCHS to operate continually for four or five years without depot-level assistance. It is recommended that the LCHS system component overhauls and repairs be scheduled to coincide with depot repairs to the pumps.

This overall LCHS maintenance strategy assumes that the ship's force will continue to perform PMS as scheduled or as recommended by this analysis and that IMA assistance will be available to the combat support ships on a regular basis. It is anticipated that the LCHS availability will increase and that the intracycle maintenance required by ship's force and IMAs will decrease during future operating cycles if the LCHS component maintenance strategies proposed by this report are adopted.

*CHAPTER FOUR*

# CONCLUSIONS AND RECOMMENDATIONS

## 4.1 CONCLUSIONS

The major findings and conclusions of the SEA for the AO-177, AOE-1, and AOR-1 Class Liquid Cargo Handling Systems are summarized as follows:

- Generally, similar equipment types exhibited the same maintenance problems.
- The LCHS pumps' performance will slowly degrade as a result of the normal wearing of internal parts. Significant reductions in performance or pump failures can be expected to occur to a majority of the pumps installed by or during the fifth operational year. Pump overhauls every four years should be sufficient to maintain adequate LCHS subsystem performance.
- Configuration differences will affect the maintenance strategies of AOE-3 and -4. These two ships have a much greater fuel oil pumping capacity than the other combat support ships and could therefore be allowed to operate longer between overhauls without significantly affecting the ships' logistics mission capabilities as defined in this report.
- Ship's force personnel cannot accomplish major repairs in a timely manner, to the following LCHS equipments:
  - Liquid cargo pumps
  - Valves located in or on fuel oil tanks
  - Valves that have one side open to the sea
  - Valves 18 IPS or larger
  - Hydraulic actuators located in or on fuel oil tanks
- The following LCHS components should receive class B overhauls at the depot level:
  - Cargo pumps
  - Stripping pumps
  - Motors

- - Certain valves
  - Turbine governors
- No individual valve or indicator exhibited a notable maintenance burden. However, the aggregate of each component group presented a significant maintenance burden for ship's force and IMAs.
- Lube oil cleanliness is the most significant factor affecting turbine and turbine governor availability.
- General LCHS maintenance accounted for almost 115 maintenance man-hours per ship operating year. No individual repair in the category occurred frequently enough or on a regular enough basis to warrant planned intracycle maintenance. However, it is anticipated that these maintenance actions will continue to occur randomly during future operating cycles.

## 4.2 RECOMMENDATIONS

Recommendations for scheduled corrective and restorative maintenance actions that are to be accomplished by depots or IMAs are summarized in Table 4-1.

Improvements to the liquid cargo handling system equipments are categorized as follows:

Design Improvements

Recommended shipalts, ordalts, and field changes

Recommended equipment redesign or replacement

Maintenance Strategy Improvements

PMS changes

Policy

Support Improvements

ILS improvements

Maintenance-capability improvements

Other

These recommended improvements are summarized in Table 4-2. No improvements were identified for the Design Improvement and Support Improvement categories.

Table 4-1. RECOMMENDED IMA AND DEPOT CORRECTIVE AND RESTORATIVE MAINTENANCE ACTIONS

| Task Number | | | Component or System | Quantity per Ship | Task Description | Level of Repair | Applicable Ships | Repair Estimate | Task Frequency | Reference Section |
|---|---|---|---|---|---|---|---|---|---|---|
| Task Type | SWAB | No. | | | | | | | | |
| Q | 544-2 | 1 | Lube Oil Coolers (Turbines) | 9-10 | Flush, chemically clean, and repair three lube oil coolers | IMA | AOE-1 and -2 | 60 man-hours per task | 2.5 years | 3.2.1.1 |
| E | 544-2 | 1 | Governors (Turbines) | 9-10 | Accomplish class B overhead | Depot | All AOE-1 Class ships | 20 man-days per governor | 48 months | 3.2.1.1 3.3 |
| Q | 544-2 | 2 | Turbines (Not to include governors) | 9-10 | Accomplish class C repairs indicated by performance tests and inspections | Depot | All AOE-1 Class ships | 30 man-days per turbine | 48 months | 3.2.1.1 3.3 |
| Q | 544-1/2 | 3 | LCHS Valves | * | Repair or overhaul valves as needed | IMA | AOE-1 Class | 60 man-hours | 12 months | 3.2.2.1 |
| | | | | | | | AOR-1 Class | 110 man-hours | 12 months | 3.2.2.1 |
| E | 544-1/2 | 2 | LCHS Valves | * | Class B overhaul valves:<br>• located in or on fuel oil tanks<br>• which open to the sea<br>• 18-IPS or larger | Depot | All AOE-1 and AOR-1 Class ships | 1300 man-days | ROH | 3.2.2.1 |
| Q | 544-1/2 | 4 | LCHS Valves | * | Repair all general purpose LCHS valves not repaired by Task E-544-1/2-2 | Depot | All AOE-1 and AOR-1 Class ships | 400 man-days | ROH | 3.2.2.1 |
| E | 544-2 | 3 | LCHS Valves | * | Overhaul and reset all LCHS relief valves and dual purpose exhaust/relief valves | Depot | AOE-1 Class | 75 man-days | ROH | 3.2.2.1 |
| | | | | | | | AOR-1 Class | 65 man-days | ROH | 3.2.2.1 |
| E | 544-2 | 4 | Cargo Pumps (3000 GPM) | 9 | Class B overhaul cargo pumps to include but not be limited to the following: | Depot | AOR-1 Class | 43 man-days per pump | 48 months | 3.2.3.1 and 3.3 |
| | | | | 9 | • Disassemble pumps<br>• Check shaft for trueness | | AOE-1 and -2 | 43 man-days per pump | 48 months | 3.2.3.1 and 3.3 |
| | | | | 6 | • Install new casing and impeller wearing rings<br>• Install new shaft sleeves<br>• Install new bearings, packing, and scals<br>• Balance rotating units<br>• Reassemble using new gaskets and fasteners<br>• Realign piping to unit<br>• Perform operational test | | AOE-3 and -4 | 43 man days per pump | 60 months | 3.2.3.1 and 3.3 |
| E | 544-2 | 5 | Cargo Pumps (6000 GPM) | 3 | Class B overhaul cargo pumps to include but not be limited to the subtasks listed in Tasks E-544-2 and -4 | Depot | AOE-3 and -4 | 46 man-days per pump | 60 months | 3.2.3.1 and 3.3 |
| E | 544-2 | 6 | Stripping Pumps | 3-7 | Class B overhaul stripping pumps to include but not be limited to the subtanks listed in Task E-544-2-4 | Depot | All AOE-1 and AOR-2 Class ships | 10 man-days per pump | 60 months | 3.2.3.1 and 3.3 |

*Exact quantities per ship could not be determined.

(continued)

Table 4-1. (continued)

| Task Number | | | Component or System | Quantity per Ship | Task Description | Level of Repair | Applicable Ships | Repair Estimate | Task Frequency | Reference Section |
|---|---|---|---|---|---|---|---|---|---|---|
| Task Type | SWAB | No. | | | | | | | | |
| Q | 544-1/2 | 5 | LCHS Indicators | * | Repair and calibrate the LCHS indicators, to include gages, motors, sight glasses, and light indicators, as necessary | IMA | AOE-1 Class | 85 man-hours | 12 months | 3.2.4.1 |
| | | | | | | | AOR-1 Class | 30 man-hours | 12 months | 3.2.4.1 |
| E | 544-1/2 | 7 | LCHS Indicators | * | Verify the operation of all LCHS indicators, to include all LCHS meters, gages, sight glasses, and light indicators, and repair and calibrate those indicators as found necessary | Depot | AOE-1 Class | 55 man-days | ROH | 3.2.4.1 |
| | | | | | | | AOR-1 Class | 40 man-days | ROH | 3.2.4.1 |
| Q | 544-1 | 6 | LCHS Actuators | * | Accomplish class C repairs to all hydraulic actuators | Depot | All AOE-1 and AOR-1 Class ships | 30 man-days | ROH | 3.2.5.1 |
| E | 544-2 | 8 | Stripping Pump Motors | 3-7 | Class B overhaul | Depot | AOR-1 Class | 6 man-days per motor | ROH | 3.2.6.1 |
| | | | | | | | AOE-1 Class | 8 man-days per motor | ROH | 3.2.6.1 |
| E | 544-2 | 9 | Cargo Pump Motors | 9-11 | Class B overhaul | Depot | AOR-1 Class | 12 man-days per motor | ROH | 3.2.6.1 |
| Q | 544-1 | 7 | LCHS | N/A | Accomplish miscellaneous system repairs as necessary | IMA | All AOE-1 and AOR-1 Class ships | 85 man-hours per task | 12 months | 3.2.7.1 |
| M | 544-1 | 1 | LCHS Subsystems | 2-3 | Accomplish subsystem test IAW NSTM 9150 (do not accomplish AVGAS subsystem tests if AVGAS capability has been removed) | Depot | All AOE-1 and AOR-1 Class ships | 20 man-days per subsystem | ROH | 3.2.7.1 |
| Q | 544-1 | 8 | LCHS Subsystems | 2-3 | Accomplish subsystem repairs as a result of Task M-544-1-1 tests | Depot | All AOE-1 and AOR-1 Class ships | 15 man-days per subsystem | ROH | 3.2.7.1 |
| M | 544-1 | 2 | LCHS Hydraulic Subsystem | 1 | Accomplish hydraulic subsystem "hydrostatic tests" IAW NSTM 9210 and NSTM 9480 | Depot | All AOE-1 and AOR-1 Class ships | 5 man-days | ROH | 3.2.7.1 |
| Q | 544-1 | 9 | LCHS Hydraulic Subsystem | 1 | Accomplish hydraulic subsystem repairs which are indicated necessary as a result of Task M-544-1-2. | Depot | All AOE-1 and AOR-1 Class ships | 10 man-days | ROH | 3.2.7.1 |

*Exact quantities per ship could not be determined.

*Table 4-2.* RECOMMENDED IMPROVEMENTS

| Component | Number | Recommendation | Reference Section |
|---|---|---|---|
| Maintenance Strategy Improvements - PMS Changes | | | |
| Turbines | 1 | Change task Q-3 of MIP E-36/8-AO to Q-3R and add a note to accomplish this task quarterly and when directed as a result of lube oil inspection (R-1). | 3.2.1.1 |
| Turbines | 2 | Make the following changes to MIP E-36/11-AO:<br>• Add "and daily when operating" to the note of task R-1W.<br>• Change PMS task 18M-3R to S-( )R.<br>• Include steps on MRC AO-Q325-N (R-1W) for sampling and inspecting the governor lube oil and renewing that lube oil when indicated to be necessary. | 3.2.1.1 |
| Maintenance Strategy Improvements - Policy | | | |
| LCHS | 3 | Overhaul or repair the LCHS components when the cargo pumps are overhauled. | 3.3 |
| Other | | | |
| LCHS | 4 | Adopt the same maintenance strategy for AO-177 Class ships as that recommended for AOE-1 and AOR-1 Class ships until sufficient AO-177 Class maintenance data are available to determine an appropriate maintenance strategy. | 3.2 |
| Valves | 5 | Initiate a study to identify the following valves:<br>• All valves located in or on fuel oil tanks.<br>• All valves that open to the sea.<br>• All valves 18 IPS or larger. | 3.2.2.1 |

# APPENDIX A

## SYSTEM BOUNDARIES FOR LCHS

This appendix comprises portions of the SWAB description pages excerpted from a copy of Ship Work Authorization Boundaries for Surface Ships, NAVSEA 0909-LP-098-6010, dated March 1981. It defines the boundaries of the Liquid Cargo Handling System and was used as a primary reference source in establishing the system boundaries for this analysis.

All major components subjected to analysis in this report are listed below within their respective SWAB groups:

SWAB: 544-1 Liquid Cargo Handling Systems

| | | | |
|---|---|---|---|
| SWLIN: | 54411 | Title: | Liquid Cargo Handling (F.O.) |
| | 54412 | | Liquid Cargo Handling (JP-5) |
| | 54413 | | Liquid Cargo Handling (MOGAS) |
| | 54414 | | Liquid Cargo Handling (AVGAS) |

Includes authorized work for:

Receiving, stowing, transferring, and delivery of liquid cargo, fuel oil, JP-5 MOGAS, AVGAS, lube oil. Provides for inspection, repair, and test.

Associated Equipment:

| | |
|---|---|
| $CO_2$ blanketing | Nozzles |
| $CO_2$ inerting system | *Piping |
| $CO_2$ purging system | Priming tanks |
| Eductors | Solenoids |
| Filters | Strainers |
| Hoses | *Thermometers |
| Hose reels | *Valves |
| Operating gear | Vents |
| Motor | |

Asterisks (*) identify equipments addressed in this analysis.

SWAB: 544-2 Pumps and Controllers, Liquid Cargo Handling

| | | |
|---|---|---|
| SWLIN: 54421 | Title: | Pumps, Liquid Cargo Handling (F.O.) |
| 54422 | | Pumps, Liquid Cargo Handling (JP-5) |
| 54423 | | Pumps, Liquid Cargo Handling (MOGAS) |
| 54424 | | Pumps, Liquid Cargo Handling (AVGAS) |

Includes authorized work for:

Pump Inlet to Pump Outlet, Including Prime Mover, Power Source, and Controllers. Provides for inspection, repair, and test.

Associated Equipment:

*Controllers
Fittings attached to pump
Foundation
*Gauges
Hand Pumps
*Motors
Piston
Power cable between panel and motor
*Pumps
Switches
*Turbine
*Valves

Asterisks (*) identify equipments addressed in this analysis.

*APPENDIX B*

# LCHS INSTALLATION CONFIGURATION FOR AOE-1, AOR-1, AND AO-177

The LCHS discussed in this report is composed principally of the components listed in Table B-1. The table provides detailed information regarding the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull. In some instances it appears from the table that particular key components are not installed on some of the ships. In those instances, one of the following conditions exists:

- The component has no separate APL.
- The component is not listed in the applicable type commander's COSAL, and no data were reported in MDS or CASREP data for that component.

Table B-1. CONFIGURATION OF LCHS INSTALLATION FOR AOE-1, AOR-1, AND AO-177 CLASS SHIPS

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| PUMP RTY PWR 400GPM 150PSI | 016200345 | JP-5 STRIPPING | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 4 | | | |
| PUMP RTY PWR 400GPM 150PSI | 016200132 | JP-5 STRIPPING/NSFO STRIPPING | | | | | | | | 7 | 3 | | 2 | |
| PUMP CTFGL 3000GPM 150PSI | 016180267 | JP-5 PUMP | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016180266 | NSFO PUMP | 3 | 3 | 3 | 3 | 3 | 3 | | | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016180265 | JP-5 PUMP | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016180264 | NSFO PUMP | 3 | 3 | 3 | 3 | 3 | 3 | | | | | | |
| PUMP CTFGL 3000GPM | 016021474 | DFM/JP-5 PUMP | | | | | | | | | | | | 8 |
| PUMP CTFGL 1750GPM 150PSI | 016031653 | AVGAS PUMP | | | | | | | | | | 1 | 1 | |
| PUMP CTFGL 6000GPM 150PSI | 016031737 | NSFO PUMP | | | | | | | | | | 2 | 2 | |
| PUMP CTFGL 6000GPM 150PSI | 016031738 | JP-5 PUMP | | | | | | | | | | 1 | 1 | |
| PUMP CTFGL 3000GPM 150PSI | 016031739 | NSFO PUMP | | | | | | | | | | 3 | 3 | |
| PUMP CTFGL 3000GPM 150PSI | 016201740 | JP-5 PUMP | | | | | | | | | | 3 | 3 | |
| PUMP RTY PWR 400GPM 150PSI | 016200251 | JP-5 STRIPPING PUMP | | | | | | | | | | 2 | 2 | |
| PUMP RTY PWR 200GPM 130PSI | 016200253 | AVGAS STRIPPING PUMP | | | | | | | | | | 1 | 1 | |
| PUMP RTY PWR 200GPM 150PSI | 016200419 | JP-5/NSFO STRIPPING PUMP | 2 | 5 | 2 | 2 | 2 | 2 | | | | | | |

(continued)

Table B-1. (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| PUMP CTFGL 875GPM 100PSI | 016880002 | AVGAS PUMP | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| PUMP RTY HND 5GPM 600PSI | 017750001 | HYDRAULIC CONTROL STATION | | | | | | | | 46 | 46 | 18 | 18 | |
| PUMP AXIAL PSTN 15GPM 3000PSI | 019160423 | CARGO TANK VALVE SYSTEM | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| PUMP AXIAL PSTN 15GPM 1500PSI | 019160427 | CARGO TANK VALVE SYSTEM | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 2 | 2 | |
| PUMP CTFGL 3000GPM 150PSI | 016000410 | JP-5 PUMP | | | | | | | | 3 | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016000413 | NSFO PUMP | | | | | | | | 3 | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016000414 | NSFO | | | | | | | | 3 | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016032347 | JP-5/DISTILLATE PUMP | | | | | | | 9 | | | | | |
| PUMP CTFGL 3000GPM 150PSI | 016210202 | JP-5 PUMP/NSFO PIPING | | | | | | | | | 9 | | | |
| TURBINE STM | 057950153 | NSFO PUMP | | | | | | | | | | 2 | 2 | |
| TURBINE STM | 057950154 | JP-5 PUMP | | | | | | | | | | 1 | 1 | |
| TURBINE STM | 057950155 | JP-5 PUMP | | | | | | | | | | 3 | 3 | |
| TURBINE STM | 057950156 | NSFO PUMP | | | | | | | | | | 3 | 3 | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| TURBINE STM | 057950157 | AVGAS PUMP | | | | | | | | | | 1 | 1 | |
| TURBINE STM | 057950098 | JP-5 PUMP | | | | | | | | 3 | | | | |
| TURBINE STM | 057950099 | NSFO PUMP | | | | | | | | 3 | | | | |
| TURBINE STM | 057950100 | | | | | | | | | 3 | | | | |
| TURBINE STM | 057950112 | NSFO PIPING | | | | | | | | | 6 | | | |
| TURBINE STM | 057950113 | JP-5 PUMP | | | | | | | | | 3 | | | |
| METER LIQ GAS 8" 250PSI 1750GPM | 103020010 | AVGAS PIPING | | | 1 | | 1 | | | | | | | |
| METER LIQ FO 8" 150PSI 4000GPM | 103020020 | JP-5 CARGO PIPING | | | | | | | | | | 6 | 6 | |
| METER LIQ FO 10" 150PSI 4000GPM | 103020021 | NSFO CARGO PIPING | | | | | | | | | | | 6 | |
| METER LIQ GAS 6" 150PSI 2000GPM | 103020022 | AVGAS CARGO PIPING | | | | | | | | | | 2 | 2 | |
| METER LIQ FO 8" 150PSI 3000GPM | 103020008 | AVGAS PIPING | | | | | | | | | 2 | | | |
| METER LIQ JP-5 8" 250PSI 3000GPM | 103020009 | JP-5 PIPING | | | | | | | | | 4 | | | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| PANEL RMT VL OPER | 500650004 | HYDRAULIC CONTROL, CARGO TANK VALVE SYS | 41 | 16 | 15 | 16 | 16 | 16 | | | | | | |
| PANEL CONT | 500650015 | HYDRAULIC CONTROL, CARGO TANK VALVE SYS | | 1 | 1 | 1 | 1 | 1 | | | | | | |
| PANEL ALARM | 502310073 | LCS | | | | | | | | | | 1 | 1 | |
| PANEL VALVE OPERATING | 508880006 | HYDRAULIC CONTROL, TANK VALVE SYS | | | | | | | 1 | | | | | |
| MANIFOLD ASSY HYD | 520350017 | HYDRAULIC CONTROL, CARGO TANK LEVEL SYS | | | | | | | | | | 8 | 8 | |
| MANIFOLD ASSY HYD | 520350018 | HYDRAULIC CONTROL, CARGO TANK LEVEL SYS | | | | | | | | | | 6 | 12 | |
| MANIFOLD ASSY HYD | 520350019 | HYDRAULIC CONTROL, CARGO TANK LEVEL SYS | | | | | | | | | | 26 | 26 | |
| | 520570011 | JP-5 PIPING/NSFO PIPING | 42 | 22 | 24 | 22 | 4 | 22 | 26 | | | | | |
| | 520570017 | HYDRAULIC CONTROL, CARGO TANK VALVE SYS | | | | | | | | | 2 | 28 | 28 | |
| | 520570018 | JP-5 PIPING/NSFO PIPING | 12 | 8 | 8 | 8 | 4 | 8 | | | | | | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| | 520570019 | | | | | | | | | | | 28 | 4 | |
| ACTUATOR RTY ROBOTARM, HYD OPER | 520570003 | CARGO TANK VALVE SYSTEM | | | | | | | | 16 | | | | |
| ACTUATOR RTY ROBOTARM, HYD OPER | 520570004 | CARGO TANK VALVE SYSTEM | | | | | | | | 32 | | | | |
| STARTER MOTOR 440V 1SPD | 151207618 | AVGAS STRIPPING PUMP | | | | | | | | | | 1 | 1 | |
| STARTER MOTOR 440V 1SPD | 151208252 | NSFO PUMP | 6 | | 6 | 6 | 6 | 6 | | | | | | |
| STARTER MOTOR | 151208260 | AVGAS PUMP | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| STARTER MOTOR 440V 1SPD | 151208262 | JP-5 PUMP | 3 | 3 | 3 | 3 | 3 | 3 | | | | | | |
| STARTER MOTOR 440V 1SPD | 151205309 | JP-5 STRIPPING PUMP | | | | | | | | 3 | 3 | | | |
| MOTOR AC 440V 25HP | 174751520 | AVGAS STRIPPING PUMP | | | | | | | | | | 1 | 1 | |
| MOTOR AC 440V 50HP | 174751521 | JP-5 STRIPPING PUMP | | | | | | | | | 3 | 2 | 2 | |
| MOTOR AC 460V 50HP | 174752975 | JP-5 STRIPPING PUMP | | 1 | 1 | 1 | 1 | 1 | | | | | | |
| MOTOR AC 440V 75HP | 175504124 | AVGAS PUMP | 2 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| MOTOR AC 440V 30HP | 175504129 | JP-5 PUMP | 3 | 3 | 3 | 3 | 3 | 3 | | | | | | |

(continued)

Table B-1. (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| MOTOR AC 440V | 175504130 | NSFO PUMP | 6 | 6 | 6 | 6 | 6 | 6 | | | | | | |
| MOTOR AC 460/230V 50HP | 174031308 | JP-5 STRIPPING PUMP | 1 | | | | | | | | | | | |
| MOTOR AC | 174031705 | DFM/JP-5 PUMP | | | | | | | | | | | | |
| FLOWMETER | 380180018 | NSFO PIPING | | | | | 7 | 13 | | | | | | 8 |
| FLOWMETER | 380180008 | NSFO PIPING | | 5 | | 5 | | | | | | | | |
| INDICATOR REC TANK LEVEL | 384890324 | TANK LEVEL INDICATING SYS | | 2 | | 2 | | | | | | 28 | | ✓ |
| INDICATOR REC TANK LEVEL | 384890338 | TANK LEVEL INDICATING SYS | | 2 | | 3 | 3 | 3 | 14 | 10 | 1 | 6 | 8 | 6 |
| INDICATOR LIQ LVL TRANSMITTER | 384890873 | TANK LEVEL INDICATING SYS | 15 | 13 | 19 | 11 | 13 | 4 | 11 | 10 | 3 | | 24 | 2 |
| INDICATOR REC TANK LEVEL | 384890342 | TANK LEVEL INDICATING SYS | | | | | | | | 12 | | | | |
| RECEIVER IND TANK LVL | 384890915 | | | 1 | | | | | | | | | | |
| INDICATOR REC TANK LVL | 384890917 | TANK LEVEL INDICATING SYS | | | | | | | 6 | | | | | |
| INDICATOR LIQ LEVEL | 384890947 | | 3 | | | 2 | | | | 2 | | 9 | | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| INDICATOR ASSY & LIQ LEVEL TRMT | 384890951 | | | | | | | 2 | 1 | | | | | |
| TRANSMITTER LIQ LVL | 384920111 | TANK LEVEL IND SYS | 23 | | 18 | 4 | 23 | | | 7 | | | | |
| INDICATOR LIQ LVL | 384920125 | TANK LEVEL IND SYS | 1 | | 1 | 1 | 1 | | | | | | | |
| INDICATOR LIQ LVL | 384920126 | TANK LEVEL IND SYS | 1 | | 1 | 1 | 1 | | | | | | | |
| INDICATOR LIQ LVL TRANSMITTER | 384890926 | | | | | | | | 1 | | | | | |
| INDICATOR MULTIPOINT TEMP | 385010056 | | | | | | | | | 1 | | | | |
| INDICATOR SYS LIQ QTY | 450100543 | | | | | | | | | | | 22 | 1 | |
| INDICATOR SYS LIQ QTY | 451020074 | TANK LEVEL IND SYS | | | | | | | | | | | 1 | |
| INDICATOR SGT LIQ PSTC 18" | 452130095 | AVGAS PIPING | | | | | | | | | | 1 | 1 | |
| INDICATOR SGT LIQ PSTC 10" | 452130096 | AVGAS PIPING | | | | | | | | | | 2 | 2 | |
| INDICATOR SYSTEM LIQ QTY | 451000338 | | | | | | | | | | 8 | | | |
| INDICATOR SYSTEM LIQ QTY | 451000339 | | | | | | | | | | 50 | | | |
| INDICATOR SYSTEM LIQ QTY | 610360032 | AVGAS PIPING | | | | | | | | | | 4 | 4 | |
| INDICATOR SYSTEM LIQ QTY | 610360038 | NSFO PIPING | | | | | | | | | | 25 | 11 | |

(continued)

Table B-1. (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| CONSOLE, CARGO CONTROL | 616050210 | DFM/JP-5 | | | | | | | | | | | | 2 |
| CONSOLE STG CONT | 618020035 | | | | | | | | | | | | 1 | |
| CONSOLE | 618020036 | | | | | | | | | | | 2 | | |
| OPERATOR VL MTRDN | 619560007 | JP-5/AVGAS, NSFO PIPING | | | | | | | | | | 29 | 28 | |
| GEAR ASSY SPD DECR | 692060130 | JP-5, NSFO PUMP | | | | | | | | | | 3 | 3 | |
| | 692060131 | JP-5 PUMP | | | | | | | | | | 6 | 3 | |
| GEAR ASSY SPD DECR | 692060132 | | | | | | | | | | | 1 | 1 | |
| GOVERNOR HYD | 701110314 | JP-5/NSFO PUMP | | | | | | | | | | 9 | 9 | |
| VALVE CHK .37IPS 3000PSI | 882034502 | JP-5 PIPING | | | | | 8 | 8 | | | | | | |
| VALVE CHK STP GLB IOIPS 150PSI | 882035585 | FOS, PIPING | 9 | 6 | 6 | 6 | 6 | 6 | 6 | | | | | |
| VALVE GATE 2.5IPS 100PSI | 882040812 | AVGAS PIPING | | | | | | | | | | 1 | 1 | |
| VALVE GATE 14IPS 150PSI | 882044102 | CARGO FILLING | | | | | | | | | | 4 | | |
| VALVE GATE 10.0IPS 150PSI | 882046075 | FOS, PIPING, CARGO FILLING | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | | | | |

(continued)

Table B-1. (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| VALVE GATE 10.0IPS 225PSI | 882046153 | JP-5 PUMP | 6 | 4 | 6 | 6 | | | | | | | | |
| VALVE GATE 10IPS 150PSI | 882046258 | | 2 | 6 | 6 | 6 | 5 | 6 | | | | | | |
| VALVE GATE 18IPS 150PSI | 882046260 | | 7 | 6 | 6 | 6 | 9 | 6 | | | | | | |
| VALVE GATE 20IPS 150PSI | 882046268 | JP-5/NSFO PIPING | 5 | 6 | 5 | 5 | 4 | 4 | | | | | | |
| VALVE GATE 18IPS 150PSI | 882046269 | JP-5 PIPING | | 4 | 4 | 2 | 9 | 4 | | | | | | |
| VALVE GATE 12IPS 150PSI | 882046272 | JP-5 PIPING | | 4 | 4 | 1 | 4 | 4 | | | | | | |
| VALVE GATE 8IPS 150PSI | 882046950 | FOS, CARGO FILLING | 2 | 3 | 2 | 1 | 2 | 2 | | | | | | |
| VALVE RELF VAC 6IPS | 882117457 | NSFO PIPING | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | |
| | 882232959 | CARGO TANK VALVE SYS | 62 | 60 | 52 | 52 | | 60 | | | | | | |
| VALVE EXH × RELF GLB 8IPS | 882241179 | AVGAS/JP-5/NSFO PUMP | | | | | | | | | | | 7 | |
| VALVE EXH × RELF 10IPS | 882241419 | JP-5/NSFO PUMP | | | | | | | | | | | 3 | |
| VALVE BTFL 8IPS | 882290061 | NSFO PIPING | | | | | | | | | | | 3 | |
| VALVE BTFL 10IPS | 882290247 | JP-5 PIPING | X | X | X | | | | | | | 13 | 13 | |
| VALVE BTFL 5IPS | 882290756 | JP-5 PIPING | | | | | | | | | | 7 | 7 | |
| VALVE BTFL 8IPS | 882290758 | JP-5/NSFO PIPING | | | | | | | | 3 | 26 | 23 | 40 | |

(continued)

Table B-1. (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| VALVE BTFL 10IPS | 882290759 | JP-5 PIPING | | | | | | | | | | 21 | 8 | |
| VALVE BTFL 6IPS | 882290824 | NSFO PIPING | | | | | | | | | | 3 | 3 | |
| VALVE BTFL 8IPS | 882291065 | NSFO PIPING | | | | | | | | | | 3 | 3 | |
| VALVE BTFL 18IPS | 882291131 | JP-5/NSFO PIPING | | | | | | | | | | 9 | 9 | |
| VALVE BTFL 10IPS | 882291192 | PIPING CARGO (FOS) | 14 | 7 | 7 | 7 | 4 | 7 | | | | | | |
| VALVE BTFL 3IPS | 882291248 | JP-5 PIPING | 4 | 1 | 1 | 1 | 4 | 1 | | | | | | |
| VALVE BTFL 5IPS | 882291249 | JP-5 PIPING | 12 | 8 | 8 | 8 | 5 | 8 | | | | | | |
| VALVE BTFL 10IPS | 882291250 | JP-5 PIPING | 10 | 10 | 10 | 10 | 25 | 10 | | | | | | |
| VALVE BTFL 10IPS | 882291250 | JP-5 PIPING | | 10 | | 10 | | 10 | | | | | | |
| VALVE BTFL 12IPS | 882291251 | | 14 | 16 | 16 | 12 | 20 | 16 | | | | | | |
| VALVE BTFL 10IPS | 882291280 | JP-5 PIPING | 20 | 18 | 18 | 18 | 20 | 18 | | | | | | |
| VALVE BTFL 10IPS | 882291288 | JP-5/NSFO PIPING | 12 | 19 | 20 | 19 | 19 | 19 | | | | | | |
| VALVE BTFL 8IPS | 882291404 | AVGAS PIPING | 3 | 2 | 2 | 2 | 2 | 2 | | | | | | |
| VALVE BTFL 14IPS | 882291431 | JP-5 PIPING/NSFO PIPING | 36 | 18 | 18 | 18 | 18 | 18 | | | | | | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| VALVE BTFL 14IPS | 882291435 | JP-5 PIPING | 1 | 1 | 1 | 2 | 1 | 1 | | | | | | |
| VALVE BTFL 3IPS | 882291438 | JP-5 RECLAMATION | | | | | | | | | | 1 | | |
| VALVE BTFL 18IPS | 882291439 | JP-5/NSFO PIPING | 10 | 8 | 8 | 10 | 10 | 8 | | | | | | |
| VALVE BTFL 18IPS | 882291440 | JP-5/NSFO PIPING, CARGO TANK VALVE SYSTEM | 6 | 4 | 3 | 5 | 10 | 4 | | | | | | |
| VALVE BTFL 20IPS | 882291441 | JP-5/NSFO PIPING | 9 | 11 | 11 | 11 | 16 | 11 | | | | | | |
| VALVE BTFL 24IPS | 882291442 | JP-5/NSFO PIPING | 4 | 4 | 4 | 4 | 4 | 4 | | | | | | |
| VALVE BTFL 10IPS | 882291445 | NSFO PIPING | 2 | 2 | 3 | 2 | 11 | 2 | | | | | | |
| VALVE RELF .37IPS | 883112295 | JP-5 PIPING | | | | 6 | | 3 | | | | 4 | | |
| VALVE RELF 5IPS | 883112762 | JP-5/NSFO PIPING | 10 | 7 | 7 | 7 | 18 | 18 | | | | | | |
| VALVE RELF .37IPS | 883114063 | | 1 | 1 | 3 | 1 | 1 | 1 | | | | | | |
| VALVE RELF .37IPS | 883115025 | JP-5 PIPING | | | | | 3 | 3 | 3 | | | 4 | | |
| VALVE BTFL 10IPS | 882291645 | CARGO FILLING, JP-5 PIPING | | | | | | | 21 | | | | | |
| MANIFOLD ASSY 8VL | 882351961 | HYD CONTROL - CARGO TANK VALVE SYS | | | | | | | | | 5 | | | |

(continued)

*Table B-1.* (continued)

| Nomenclature (As Listed in APL) | APL/CID | Application | Quantity by Hull Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 | AO-177 |
| VALVE RELF .37IPS | 883111927 | JP-5 PIPING | | | | | 9 | | 9 | | | | | |
| VALVE RELF 3IPS | 883113006 | CARGO PIPING | | | | | | | | | 6 | | | |
| VALVE RELF 3IPS | 883113007 | JP-5 PIPING | | | | | | | | | 3 | | | |

*APPENDIX C*

# MAJOR DIFFERENCES IN CARGO PUMPS OF THE LIQUID CARGO HANDLING SYSTEM, BY LCHS DESIGN

Table C-1 lists the major design differences among the cargo pumps of the liquid cargo handline system within each ship class and across the three ship classes examined. These specific differences were not addressed in the text of this report unless gross maintenance-history differences were found to be the result of the design differences or the design differences affected maintenance strategy development.

Table C-2 presents a summary, by LCHS subsystem and LCHS design, of the subsystem degradation when any number of pumps are out of commission. The percentages shown reflect the loss of total subsystem pumping capacity.

*Table C-1.* LCHS DIFFERENCES: CARGO PUMPS

| Characteristics | Differences in Characteristics by Ship Design | | | | | |
|---|---|---|---|---|---|---|
| | AOE-1 | AOE-2 | AOE-3, -4 | AOR-1, -2, -3, -4, -5, -6 | AOR-7 | AO-177 |
| Cargo Pump APLs by Manufacturer | | | | | | |
| Allis - Chambers | 016000410<br>016000413<br>016000414 | | | | | |
| Fairbanks Morse | | 016210202 | | | | |
| Worthington | | | 016031653<br>016031737<br>016031738<br>016031739<br>016031740 | | 016032347 | |
| Ingersoll-Rand | | | | 016180264<br>016180265<br>016180266<br>016180267 | | |
| Johnston | | | | 016880002 | | |
| Warren | | | | | | 016021474 |
| Cargo Pump Capacities (and Number Installed per Hull) | 3,000 gpm (9) | 3,000 gpm (9) | 1,750 gpm (1)<br>3,000 gpm (6)<br>6,000 gpm (3) | 872 gpm (2)<br>3,000 gpm (9) | 3,000 gpm (9) | 3,000 gpm (8) |
| Total Pumping Capacities by Subsystem | | | | | | |
| DFM | 18,000 gpm | 18,000 gpm | 21,000 gpm | 18,000 gpm | 18,000 gpm | 15,000 gpm |
| JP-5 | 9,000 gpm | 9,000 gpm | 15,000 gpm | 9,000 gpm | 9,000 gpm | 9,000 gpm |
| AVGAS | 0 | 0 | 1,750 gpm | 1,750 gpm | 0 | 0 |

Table C-2. EFFECTS OF PUMP LOSS ON LCHS SUBSYSTEMS

| Number of Pumps Down | Subsystem Degradation Percentage | | | | | |
|---|---|---|---|---|---|---|
| | AOE-1 | AOE-2 | AOE-3, -4 | AOR-1, -2, -3, -4, -5, -6 | AOR-7 | AO-177 |
| DFM | | | | | | |
| a. 1 | 17 | 17 | 14 or 28 | 17 | 17 | 20 |
| b. 2 | 33 | 33 | 28 or 43 or 57 | 33 | 33 | 40 |
| c. 3 | 50 | 50 | 43 or 57 or 71 | 50 | 50 | 60 |
| d. 4 | 67 | 67 | 71 or 86 | 67 | 67 | 80 |
| e. 5 | 83 | 83 | 100 | 83 | 83 | 100 |
| f. 6 | 100 | 100 | N/A | 100 | 100 | N/A |
| JP-5 | | | | | | |
| a. 1 | 33 | 33 | 20 or 40 | 33 | 33 | 33 |
| b. 2 | 67 | 67 | 40 or 60 | 67 | 67 | 67 |
| c. 3 | 100 | 100 | 60 or 80 | 100 | 100 | 100 |
| d. 4 | N/A | N/A | 100 | N/A | N/A | N/A |
| AVGAS | | | | | | |
| a. 1 | N/A | N/A | 100 | 50 | N/A | N/A |
| b. 2 | N/A | N/A | N/A | 100 | N/A | N/A |

## *APPENDIX D*

## SUMMARY OF CASREP INFORMATION FOR THE LIQUID CARGO HANDLING SYSTEMS

The 27 CASREPs reported by the AO-177, AOE-1, and AOR-1 class ships were distributed among six general categories -- DFM/JP-5 cargo pumps, AVGAS cargo pumps, JP-5 stripping pumps, cargo pump turbines, valves, or hydraulic power units -- and into appropriate subcategories on the basis of the initial cause reported for each CASREP. This information is presented in Table D-1. The table also shows the total number of CASREPs reported against each different LCHS design for each initial cause, together with the total number of CASREP downtime man-hours due to supply and maintenance.

*Table D-1.* LCHS CASREP SUMMARY

| Reason for CASREP | Number of CASREPs | | | | CASREP Downtime Man-Hours | | |
|---|---|---|---|---|---|---|---|
| | AO-177 | AOE-2 | AOE-3, AOE-4 | AOR-1 - AOR-6 | Due to Supply | Due to Maintenance | Total |
| 1. DFM/JP-5 Cargo Pump | | | | | | | |
| A. Gauge line cracked | 1 | | | 1 | 0 | 2,583 | 2,583 |
| B. Rotating essembly misaligned | | | 1 | 2 | 0 | 4,978 | 4,978 |
| C. Priming supply line blocked | | | | 1 | 0 | 702 | 702 |
| D. Priming pump casing warped | | | | 1 | 0 | 1,708 | 1,708 |
| E. Chrome plating separating from pump shaft | | | | 1 | 0 | 1,499 | 1,499 |
| F. Gaskets/seals leaking | | | | 1 | 0 | 838 | 838 |
| G. Adjustment not backed off | | | 1 | 1 | 0 | 1,823 | 1,823 |
| H. Unknown | | | | | 0 | 1,488 | 1,488 |
| Subtotal | 1 | 0 | 2 | 8 | 0 | 15,619 | 15,619 |
| 2. AVGAS Cargo Pump | | | | | | | |
| A. Worn bearings | | | | 1 | 0 | 9,999 | 9,999 |
| Subtotal | 0 | 0 | 0 | 1 | 0 | 9,999 | 9,999 |
| 3. JP-5 Stripping Pump | | | | | | | |
| A. Vanes penetrated bearings and seals | | | | 1 | 124 | 13 | 137 |
| B. Relief valve line cracked | 1 | | | | 0 | 1,983 | 1,983 |
| Subtotal | 1 | 0 | 0 | 1 | 124 | 1,996 | 2,120 |
| 4. Cargo Pump Turbine | | | | | | | |
| A. Lube oil pump gears worn | | 1 | | | 768 | 934 | 1,702 |
| B. Unknown | | | 1 | | 0 | 2,778 | 2,778 |
| Subtotal | 0 | 1 | 1 | 0 | 768 | 3,712 | 4,480 |
| 5. Valves | | | | | | | |
| A. Bushings worn/broken | 1 | | | | 1,112 | 1,025 | 2,137 |
| B. Seats leak | | | | 9 | 2,160 | 11,699 | 13,859 |
| Subtotal | 1 | 0 | 0 | 9 | 3,272 | 12,724 | 15,996 |
| 6. Hydraulic power unit | | | | | | | |
| A. Unknown | | | | 1 | 0 | 270 | 270 |
| Subtotal | 0 | 0 | 0 | 1 | 0 | 270 | 270 |
| Total | 3 | 1 | 3 | 20 | 4,164 | 44,320 | 48,484 |

Note: No CASREPs were reported by AOE-1 or AOR-7.

# *APPENDIX E*

## SHIPALT STATUS FOR LIQUID CARGO HANDLING SYSTEM

Table E-1 shows the status of current approved shipalts for the AO-177, AOE-1, and AOR-1 Class liquid cargo handling systems. The source for the completion codes listed on the table is the type commander status of Shipalt Management Information System (SAMIS) as of 2/11/82.

The status codes used are defined as follows:

A = Applicable, not authorized for accomplishment

B = Applicable, authorized for accomplishment

C = Completed

Table E-1. SHIPALT STATUS

| Number | Description | Status by Hull Number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AOR-1 | AOR-2 | AOR-3 | AOR-4 | AOR-5 | AOR-6 | AOR-7 | AOE-1 | AOE-2 | AOE-3 | AOE-4 |
| AOE-368 | Removal of AVGAS capability | | | | | | | | C | C | A | A |
| AOE-301 | Install cargo F.O. × conn. isolation valve | | | | | | | | A | | | |
| AOE-238 | HM&E install JP-5 reclamation system | | | | | | | | A | A | C | B |
| AOR-30 | HM&E install JP-5 reclamation system | A | C | C | B | A | B | | | | | |
| AOR-251 | Safety mods cargo JP-5 pump room | A | A | C | A | A | A | | | | | |
| AOR-346 | Pipe guard for JP-5 risers | C | A | A | A | A | A | A | | | | |
| AOR-432 | Cargo fresh water t› nsfer system | A | B | A | A | A | A | A | | | | |

*APPENDIX F*

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for AO-177, AOE-1, and AOR-1 Class ships for the period 1 January 1975 through 30 July 1981.
2. CASREPs for AO-177, AOR-1, and AOR-1 Class ships for the period 1 January 1978 through 31 July 1981.
3. COMNAVSURFLANT and COMNAVSURFPAC Type Commander's Coordinated Shipboard Allowance Lists (COSALs), dated 1 June 1981 and 1 July 1981, respectively.
4. Allowance parts lists (APLs) for selected components of the AO-177, AOR-1, and AOR-1 Class liquid cargo handling systems.
5. Maintenance index pages (MIPs) and maintenance requirement cards (MRCs) for the AO-177, AOE-1, and AOR-1 Class liquid cargo handling systems.
6. Shipalt briefs and SAMIS shipalt information.
7. Common Configuration Class Lists (CCCLs) for AO-177, AOE-1, and AOR-1 Class ships.
8. Ship Alteration and Repair Packages (SARPs):
   - AOE-1 - 7/2/76 through 5/31/77
   - AOE-1 - 9/22/80 through 11/27/81
   - AOE-2 - 10/20/76 through 8/20/77
   - AOE-3 - 9/28/79 through 11/3/80
   - AOE-4 - 1/13/82 through 1/12/83
   - AOE-4 - Not dated
   - AOR-1 - 12/2/78 through 9/2/79
   - AOR-2 - Not dated
   - AOR-3 - 12/3/79 through 9/14/80
   - AOR-4 - 3/2/81 through 12/4/81
   - AOR-5 - 3/1/82 through 12/3/82
   - AOR-6 - Not dated
   - AOR-7 - 10/4/82 through 7/1/83

9. NAVSEA SN345-AB-MNO-101, *Tank and Indicating (TLI) System*, dated 15 July 1978.

10. NAVSHIPS 0947-087-1010, *Technical Manual Covering 6000 and 3000 GPM Liquid Cargo Pumps for AOE-3 and -4.*

11. NAVSHIPS 0947-121-0010, *Technical Manual for Motor Driven Self-Priming and Non-Self-Priming Cargo Fuel Oil Ballast Pumps and Cargo JP-5 and Ballast Pumps*, dated 20 July 1970.

12. NAVSHIPS 0948-050-0010, *Technical Manual for Hydraulic Remote Valve Operating/Indicating System*, dated 17 November 1969.

13. NAVSHIPS 0948-055-3010, *Hydraulic Manifold Assemblies*, Volume I, dated 30 September 1967.

14. NAVSHIPS 0948-055-4010, *Instructions for Installation, Operation, and Maintenance of Model MRB-2150A Robotarm Hydraulic Valve Actuators*, Volume I, dated January 1968.

15. NAVSEA 0965-LP-060-1010, *Type II Operation and Maintenance Manual for GEMS Tank Level Indicating (TLI) System*, dated November 1972.

16. NAVSHIPS 0947-147-4010, *Type 1 Cargo Fuel Stripping Pump*, dated 5 February 1970.

17. NAVSHIPS 0947-147-0010, *Type 1 Fuel Oil Tank Stripping Pump*, Change 1, dated June 1975.

18. NAVSHIPS 0947-201-0010, Johnston Pump Company.

19. NAVSEA 0905-LP-496-2080, *Ship Information Book for DD-963 Class Ship, Volume 7, Underway Replenishment Systems*, Change 2, dated 29 September 1977.

20. NAVSEA 0900-LP-098-6010, *Ship Work Authorization Boundaries for Surface Ships*, March 1981.

21. *AOE-1 Class Ship Systems Definition and Index (EIC Staging Diagrams)*, dated February 1973.

22. *Equipment Identification Code Master Index*, NAMSO 4790.E2579, dated January 1980.

23. OPNAV Notice 4710, *Pacific and Atlantic Fleets Overhaul Schedules*, fiscal years 1981-1987, dated 16 June 1981.

24. *System Engineering Analysis of Ship's Service Turbine Generator Sets Installed on AFS-1, AOE-1, and AOR-1 Class Ships*, dated March 1981.

25. *System Engineering Analysis of Forced Draft Blowers Installed on AFS-1, AOE-1, and AOR-1 Class Ships*, ARINC Research Publication 2614-11-4-2494, dated July 1981.

26. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual*, Volumes I, II, and III, June 1973.

27. OPNAVINST C3501.2E, *Naval Warfare Mission Areas*, 19 October 1977.

28. Shipalt Information Manuals: AOE-1 Class 1980 and AOR-1 Class 1980

29. Naval Ship Technical Manuals

| Old Number | New Number | Title |
|---|---|---|
| 9150 | 542 | *Gas and JP-5 Fuel Systems* |
| 9210 | 556 | *Hydraulic Equipment* |
| 9480 | 505 | *Piping* |

30. Ship Visits:

- AOE-3 - 20 January 1982
- AOR-4 - 20 January 1982
- AO-177 - 27 October 1981
- AO-178 - 21 January 1982

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